IMPACT OF ORIENTATION ON RESIDENTIAL PROPERTY VALUE

HE XIXIA

NATIONAL UNIVERSITY OF SINGAPORE

2006

IMPACT OF ORIENTATION ON RESIDENTIAL PROPERTY VALUE

HE XIXIA
(M. Eng, XAUAT)

A THESIS SUBMITTED
FOR THE DEGREE OF MASTER OF ESTATE MANAGEMENT

DEPARTMENT OF REAL ESTATE
NATIONAL UNIVERSITY OF SINGAPORE
2006

Acknowledgement

I would like to express my sincere gratitude and appreciation to my supervisor, Professor Yu Shi Ming, for his guidance and mentorship in this work and for his help and support during the two years of my master study.

I would also like to thank Professor Ong Seow Eng and Professor Fu Yuming for their constructive comments.

I wish to express my great gratitude for my friends, Chen Xin and Wu Jianfeng, for their kindly help in my research.

Table of Contents

Summary

Factors affecting property prices usually include structural variables, accessibility variables, neighborhood variables and environmental variables. However, in different locations, under different market influence, the extents to which these variables have an impact are unlikely to be the same. These may be due to different environment and climatic conditions as well as cultural and social influences.

This dissertation aims to determine the impact of orientation on residential property prices using 3D modeling technique and compare house price determinants between Beijing and Singapore.

Orientation is important, especially in the context of high-rise residential properties, which form the bulk of housing in Beijing and Singapore, because it determines sunlight duration and the view that can be seen from a housing unit. However research on the impact of orientation on house value is rather limited. This is probably due to the difficulties in measuring orientation. The capacity to do this has been significantly enhanced in recent years with the emergence of some 3D modeling software. Using such tools, sunlight duration of each residential property can be identified and incorporated into the traditional hedonic pricing model.

The results show that 3D sunlight analysis is applicable in the study of house price.

We find that while the effects of structural variables are similar for both markets, the impact of environmental factors is substantially different. In Beijing, orientation with greater sunlight duration has a positive impact. In contrast, the opposite is true for the Singapore market. In terms of view, it is more significant in Singapore than in Beijing, as orientation seems to override other factors in the latter market.

The findings have three significant implications. First, house price determinants while broadly similar in different markets may be affected by local conditions such as the climate and other social and cultural traditions. Second, while house prices may be affected by similar factors in different countries, the extent of influence of these factors may be different. This implies that an intimate knowledge of local market conditions and influences is prerequisite for appraisal. Third, with the rapid increase of energy cost, issue of energy saving is more and more important. Study on orientation especially on sunlight may offer a better understanding of utilizing energy from the sun.

List of Tables

List of Figures

Chapter 1 Introduction

1.1. Background

Property value, as the main concern in the real estate industry, is a function of locational, physical, legal and economical factors. The value of property reflects its capacity to fulfill a function. With regards to residential property, factors affecting value may include structural variables (e.g., number of rooms in a house), accessibility variables (e.g., proximity to schools), neighborhood variables (e.g., local unemployment rate) and environmental variables (e.g., road noise and visibility).

Traditionally, housing markets have been extensively studied using the hedonic pricing model. This method typically uses multiple regression technique to relate property price details to the diverse characteristics of different properties (Freeman, 1993). The hedonic pricing model, derived mostly from Lancaster's (1966) consumer theory and Rosen's (1974) model, posits that a good possesses a myriad of attributes that form bundles of utility-affecting attributes valued by the consumer.

Among house characteristics, some are quantitative, such as structural variables while some are difficult to be quantified. Chau, Ng and Hung (2001) classified inherent characteristics of houses as tangible attributes and intangible attributes.

Tangible attributes are physical conditions of the property, including size, floor level, age and so on. Intangible attributes include view, developer’s good will, environmental quality, accessibility etc.

In this study, the hedonic pricing model is applied to assess the importance of house orientation on property value, which is usually hard to quantify and often ignored.

1.2. Why does house orientation matter?

The economic theory underpinning the evaluation of orientation is the same as that for any other item which in some way affects an individual's enjoyment of life or “utility”. House orientation determines the sunlight received and view obtained in a housing unit. Unlike in US, where single-family properties are dominant, the high density and high-rise nature of property in some Asia cities has led to significant variations in house orientations within the same building. Arsenio et al (2006) stated that view and exposure to sunlight varied between apartments and they featured as the attributes in information published by estate agents in Lisbon who regarded them as decision making variables.

When buying a house, people pay much attention to the direction or orientation it faces. In Chinese tradition, the direction of South is considered the best direction, especially in the northern part of the country, because facing south makes the house get more sunlight and warmth. South is also regarded as auspicious in the custom of "Fengshui". However, in countries with tropical climate, which is warm all year around, this might not be important.

In the following section, we discuss the significance of orientation from three perspectives: sunlight, view and Fengshui factors.

1.2.1. Issues about sunlight

A house is designed to conserve energy and provide a comfortable interior environment. Comfortable temperature is maintained by a combination of orientation to the sun, insulation and ventilation. Daylight is dynamic in nature, composed of diffuse skylight, reflected light, and intense, directional sunlight, all changing in intensity, direction, and spectrum as the time and weather change (Leslie, 2003). Sunlight, or direct sunlight, is the visible part of sun light spectrum. Sunlight is useful, a little bit of UV is needed for health, but the infra red is needed only when days are very cold and it is certainly not needed in summer for illumination purpose.

A clearer understanding of sunlight's value is emerging. Exciting new science is opening the possibility that sunlight has a significant impact on not just our visual system, but on our biological systems as well. Peoples' health and productivity stand to benefit. Rapid increases in energy prices have also renewed interest in sunlight as a strategy to reduce building energy costs and delay the societal costs of new power plant construction.

1.2.1.1. Energy saving

Properly positioning the house can save money on utility bills and make houses more comfortable throughout the year. Orientation is a critical component of energy efficiency and the ability of a building to properly mediate the summer and winter sun heat loads which penetrate through a building.

Less sunlight reduces air conditioning energy requirements in summer because the internal cooling load from the sun is reduced. But in winter, much sunlight can make room warmer and lower the heating load. So the issue of energy saving should be analyzed according to the specific climate and location. Blocking sunlight has other benefits, including less fading of furniture and carpets, more comfortable temperatures in rooms with large windows and less glare.

Since sunlight comes with heat and glare problems, designers must make intelligent decisions through research and thorough analysis. Careful orientation, planning and calculated shading device were all found to be of importance if the target is for an energy conscious and environmental friendly design.

1.2.1.2. Effect on human being

Although the potential for reducing energy costs and environmental emissions is substantial, another powerful impact of sunlight is on building's occupants. Buildings are constructed for people. Very few people are interested in sunlight per se, but many are interested in what it can do for their health, wealth, and safety. The research on biological effects of light suggests that people may be more alert, sleep better at night, and perhaps be more productive when they are exposed to daylight levels for at least a portion of each morning.

People care about so-called green buildings and associate sunlight with healthy buildings and indoor environmental quality. This pervasive demand by people for natural light may indeed be connected to improved human performance and well-being through sunlight's impact on aesthetics, vision, and photobiology.

1.2.1.3. Considerations in designing residential buildings

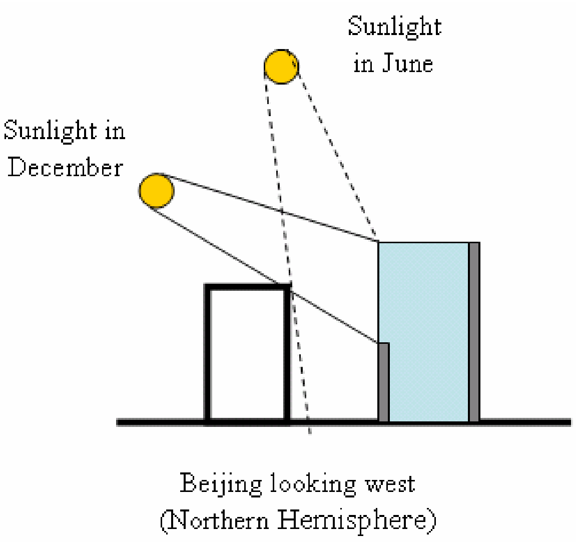
In order to make best use of sunlight, we need measures and techniques to obtain the visual aspects of sunlight without taking in the heating part of it. In any climate where the sun and its heat play a dominant role in human comfort, the direction that a house is orientated is the most effective difference we can make.

In cold areas of the northern hemisphere, many homes are designed so that they can meet at least some of their heating requirements from the sun's energy. Such homes have large south-facing windows (or north-facing if located in the southern hemisphere) that allow sunlight to heat up a room.

The north and south exposures are the easiest to deal with in the northern hemisphere. The north side can be considered the cool side as the sun spends very little time in the northern sky. The south side can be considered the sunny side, since during the course of a day the sun spends more time in the southern sky.

However, in the northern hemisphere, the sun is almost straight up in the sky at noon in summer because of latitude, which means that a southern wall can be very well shaded from the sun with a very slight overhang. The advantage is that in winter, when the sun is lower in the sky, these slight overhangs allow sunlight penetration deep into a house to provide some passive solar heating, as shown in figure 1-1.

Figure 1-1 Position of sun in the northern hemisphere



The east side of a house will take a lot of the sun's morning heat, while the west side of a house will bear the brunt of the sun's afternoon heat. In the northern hemisphere, the overheated period (the time when air conditioner will run the most, and the time to avoid going outside and doing strenuous activities) occurs between 2pm and 5pm. Since ambient heat of a day has built up, the sun's added heat will compound. For this reason, it is better to avoid purchasing a home with a lot of western exposure, even if the air conditioning system is sized specifically for it, because this home will consume more energy to keep cool than the one with less western exposure.

In summary, when architects design residential buildings, they should elongate a building along an east–west axis to avoid excessive solar heat gain. This means the longer faces of the building should face north and south where it is easy to shade the high daytime sun, and exposed walls to the west (where the hot afternoon sun comes from) should be minimized.

Considering the high-rise nature of many projects, housing units have to be designed around the lift in the center. It is not avoidable for some units to face unfavorable direction.

1.2.1.4. Limited studies on orientation

Although orientation does affect house value, its impact has not been analyzed accurately so far. Influences of those factors in valuation process are traditionally accounted for by the valuer's subject judgments. Nelson (1972) stated that among the deficiencies of residential location theory is the fact that "different site advantages of different locations, such as different views . . . are usually either neglected or ignored". This is probably due to the difficulties in measuring orientation. Site inspections consume too much time and are not accurate.

In Arsenio et al (2006), authors offered respondents choices between two different apartment options abstractly composed in terms of levels of noise, view, sunlight and housing service charge associated with existing apartment locations familiar to respondents. Respondent's perceptions of sunlight and view as well as noise were reported on a rating scale from 0 (very bad) to 100 (very good) for each of the four apartments. Such subjective perceptions are not accurate and too time-consuming to be applied in the valuation practice.

What is required, therefore, is an approach which enables orientation influence to be measured in a precise and efficient manner. The capacity to do this has been significantly enhanced in recent years with the emergence of sophisticated and relatively low-cost 3D modeling software. Using such IT tools, the sunlight and view of each residential property can be identified and incorporated into the traditional hedonic pricing model.

Another issue of concern is that the extent of orientation influence may not be the same in different countries, which are determined by local climate and social conditions. Kohlhase (1991) found that the significance of property attributes can change over time, and may vary between nations. Therefore, effect of orientation cannot be analyzed without considering house locations.

In tropical countries, like Singapore, lower temperature and better windy condition are preferred by house-purchasers. In Beijing, the opposite is true, where much sunlight in winter is highly valued. Different climate and local conditions determine that orientation plays distinct role on property value.

1.2.2. Issues about view

A scenic view is a residential amenity associated with the location of a dwelling site. A number of studies have found that buyers are willing to pay a premium for sites with a view, but exactly which amenities and the extent of their influence are less certain.

Views vary by type, such as view of river, sea, park and so on. Value of a view is difficult to measure and therefore should be examined by appraisers. Much research has been carried out on the value of view. Earlier studies used dummy variable to represent the existence of view. Recently, GIS has been extensively applied to measure the quality of view. For example, Yu and Chai (2005) studied the impact of seaview on residential properties in the east coast area of Singapore. They applied GIS and constructed Viewshed index to quantify the seaview. Results showed that purchaser would be willing to pay a premium of 15.38% of the average selling price for a totally unobstructed seaview in a private house.

While the focus of this study is on orientation rather than view, the implicit relationship between orientation and view enables this study to include the discussion on view.

1.2.3. Fengshui factors

Fengshui literally means wind and water, which are elemental forces of the earth, and are believed to have hidden power to determine the course of events. By living in harmony with environment- the wind and water of the earth- individuals can attract good luck and prosperity. The practice of Fengshui incorporates ideas of geography, ecology, astrology, aesthetics, psychology and more, and it attempts to ensure a good life through site selection and arrangement of objects on a site.

In China, traditional buildings (like the Forbidden City in Beijing) was designed according to Fengshui principles such as shapes, layout, symmetry, dimensions, height, interior decor, landscaping, orientation and weather. Scientifically, the south orientation of buildings was aligned to the stars in order to harness the cosmic energies from the universe and to protect against harsh winter wind from the north. These buildings will also avoid the placement of doors and windows on the north wall.

For centuries, Fengshui has influenced Chinese thinking and Chinese people have relied on Fengshui when designing cities, building homes and burying their ancestors. In this dissertation, we also investigated whether Fengshui still has significant effect in Beijing and Singapore.

1.3. Research Questions

This study attempts to measure the impact of orientation on property prices. Three aspects will be analyzed: sunlight, parkview and Fengshui factors. As discussed above, orientation has an implicit relationship with view and Fengshui, which are significant issues relating to sunlight. Comparison between the housing markets in Beijing and Singapore will also be made, which will help better understand the determinants of housing values in different location.

1.4. Significance and expected contribution

1.4.1. Original study on house orientation

Abundant studies have employed the hedonic pricing model to establish that property values are positively and negatively related with desirable and undesirable house characteristics. Orientation affects residents' utility and further affects property values, but research in this area is rather limited. Especially, influence of sunlight on house value has never been analyzed. The shortage of research in this area is probably due to the difficulties in the measurement of orientation. In this study, we apply state-of-the-art tool to measure sunlight, which is then applied to estimate the impact pf orientation on house price.

This study aims to develop applications of 3D tools in property valuation, which will enhance the judgment of subjective variables in valuation model. In this study, we use a sunlight analysis software SUNLIGHT to calculate the sunlight duration of every housing unit. This dissertation demonstrates how 3D sunlight modeling technique can be applied to generate data for analysis using hedonic pricing model.

1.4.2. Impact of orientation on house price

Understanding the impact of orientation on house prices will be useful to urban planners and developers. The findings and applications will be important for developing cities and countries, as increasing density will lead to more high-rise buildings.

This study may facilitate decision making by developers and help them take into account desired house attributes. Application of the model will help property developers provide quality housing, as they can better understand buyers' preferences. Buildings having attributes that satisfy buyers' needs and preferences will improve the reputation, image, and profit margin of developers. It will also assist developers in their pricing strategies of new developments. From the perspective of energy saving, knowing the sunlight duration of housing units may also help developers choose more economic wall and glass materials.

This study will also contribute to the practice of real estate valuation. In applied appraisal studies, the hedonic pricing model is commonly used in conjunction with sales comparison approach, which depends on a bundle of house attributes valued by an appraiser. Understanding the impact of orientation will help valuers determine specific adjustments objectively.

1.4.3. Comparison between Beijing and Singapore

We also compare house price determinants between Beijing and Singapore using the hedonic pricing model. Our focus is on the orientation variables including sunlight duration, parkview and Fengshui factor. The comparison among cities may help appraisers make objective judgment in different locations.

1.5. Structure of research

This dissertation contains six chapters. After an introduction in chapter 1, a thorough review of past studies, directly or indirectly related to the area of study is given in chapter 2. Chapter 3 provides descriptions of study areas and the main methodology developed in this research. Chapter 4 tests whether 3D sunlight analysis could be applied using Singapore data. The analysis is further applied to a comparative study between Beijing and Singapore in chapter 5. The final chapter gives conclusions and future studies.

Chapter 2 Literature Review

This literature review is categorized into three parts: studies on sunlight/ view/ Fengshui, application of IT tools in the real estate research and application of the hedonic pricing model.

2.1. Studies on sunlight/ view/ Fenghsui

2.1.1. About sunlight

2.1.1.1. Influence of sunlight

Leslie (2003) reviewed the literature on daylight and the design of buildings to use light from the Sun. Daylight supports human health, activities and reduces energy demand. He stated that current research suggests health, productivity, and economic benefits from daylight. Good daylight techniques include configuring buildings properly, elongating buildings along an east – west axis, locating critical visual tasks near the building’s perimeter and controlling direct sunlight. He also stated that the daylight must be designed to avoid negative effects on people. Fenestration must avoid excessive solar heat gain resulting in occupant discomfort. The brightness and distribution of the sunlight must be controlled to avoid glare and minimize degradation of fabric, artwork, and other light-sensitive objects. Heschong et al (1999) also contained research results relevant to human response to daylight.

As to the issue of energy saving, daylight case studies in Rea et al (1994) reported that energy savings were of as much as 52% along the window wall.

Glicksman et al (2002) pointed out that energy conservation in Chinese residential buildings merited attention in part due to China's large population, increased standard of living, and high volume of construction. They emphasized that the national building code in China required that each apartment receive at least one hour of direct sun per day, each day of the year. Improvements that reduce energy for heating by at least 20% over present standards were straightforward. They suggested the use of insulation materials and better windows that reduce air leakage and capture more solar energy in winter.

However, there are few studies to link the sunlight received in the housing units with property prices directly. In Arsenio et al (2006), authors analyzed the road traffic noise and stated that "the inclusion of view and exposure to sunlight made the choice experiment realistic, since these would vary between apartments and they features as attributes in information published by estate agents in Lisbon who regard them as decision making variables." The authors offered respondents choices between two different apartment options in terms of levels of noise, view, sunlight and housing service charge associated with existing apartment locations familiar to respondents. Respondent's perceptions of sunlight and view as well as noise were reported on a rating scale from 0 (very bad) to 100 (very good) for each of the four apartments.

There was no accurate and objective measurement on the sunlight in this study.

2.1.1.2. Measurement of sunlight

After admitting the significance of the sunlight, we should analyze how to measure it objectively. Accurate measurement will help us better understand house characteristics and judge property price more comprehensively. It will also assist us choose economic wall and window materials for the purpose of energy saving.

There are some earlier studies on measuring sunlight, for example, Garnett (1939) calculated time periods of sunshine and sky factors by hand; Chiba (1965) investigated the relation between insolation and distribution of houses, also calculated sunshine duration from reading of the inclination angle of a slope in the map. He found that 65.2% of houses along the ravine of Azusa were located where the sunshine duration was more than 9 hours.

Horikoshi and Kagami (1990) utilized photographs of the horizontal projection of the sky, the orthographic projection and equi-distance projection fish-eye lens to calculate the possible sunlight duration. They read the sunrise time and sunset time from the projected image and found that most houses were situated where the sunshine duration was more than 3.5 hours at the winter solstice. On the south-facing slopes the duration of sunshine was more than 5 hours at the winter solstice, however, the duration in the settlement of the north- facing slopes was less than 4 hours.

Such measurements are too time-consuming to be applied in the valuation practice. With the development of computer technique, IT tools are more and more widely used in the real estate research and industry.

2.1.1.3. Considerations in design

Kroelinger (2005) pointed that building types and site conditions vary widely for different geographic locations and from one climate type to another. For design guidelines, should consider four specific climate types, as: hot-humid, hot-arid, temperate and cool/cold. Buildings should void direct sunlight and skylight unless needed for thermal comfort.

Ne'eman and Shrifteilig (1982) stated that the availability of sunlight, its intensity, duration of daylight, cloudiness, haze, and their permanently changing nature have an immense effect on our biological and psychological well-being. For hot and temperate climates, sunshine is undesirable inside a building in such climates because of unwanted heat gains during the hot season, and glare all the year round. In regions of such climate the main consideration in efficient daylight-oriented architecture is how to admit maximum daylight into buildings and at the same time avoid undesirable effects of heat gains during the hot season, fading, deterioration of materials and glare.

Shao (1990) focused on the quantitative relationship between efficiency of land saving and building shape, size, height and arrangements of buildings, on satisfying a certain standard of sunshine. It was revealed in this paper that the arrangements of west-east direction buildings were of low efficiency of land use. It was recommended that use of these west-east arrangements should be avoided in crowded urban areas.

In order to obtain the visual aspects of sunlight without taking in the heating part of it, some scholars studied the new techniques and materials pertaining to the walls and windows.

Silverstein (1977) described a simple energy conserving window management system and its heat transfer characteristics. The device served as a quasi-active solar collector during winter daytime, provided added insulation comparable with that of vented storm windows during winter nighttime, and rejected solar heat during summer cooling periods. The results of the numerical modeling showed that the dual shade: would be approximately 90% as energy efficient as an unshaded window while intercepting direct sunlight; wound save about 40% on energy losses through a single pane window during winter nighttime; would reduce solar heat gain by about 70% during peak-power summer air conditioning periods.

2.1.2. Studies on view

View, being a qualitative and subjective variable, is difficult to measure and quantify. Earlier studies used dummy variables to consider such effect (Mcleod, 1984; Gilles et al, 1993; Seiler et al, 2001). Darling (1973) investigated the impact of distance from three urban lake parks in California. Two of the parks included a dummy variable for the impact of water view on value. This variable showed an increase in value of $2,362 and $2,756 respectively, for having a water view.

Recently, Benson et al (1998) examined the impact of views using several dummy variables. They used four levels of ocean view (full, superior partial, good partial and poor partial), two levels of lake view. Bourassa, Hoesli and Sun(2003) analyzed the multi-dimensional feature of view (type of view, scope of view, distance to coast, and quality of surrounding improvements) and empirically tested the impact of views using dummy variables.

Lake et al (1998, 2000a and 2000b) firstly applied GIS to analyze the visibility of properties in Glasgow, Scotland. The authors used Viewshed function in GIS to calculate view scores based on what is visible from the property, then weighting cells by their distance from the observer. Their results indicated the views of roads, railways and industrial estates have negative impact on property prices. However, the authors did not manage to detect any positive significant impacts of views arising from parkland, water features and vegetation.

Most recently, Yu and Chai (2005) applied GIS and 3-D modeling and constructed Viewshed index to quantify the view of Singapore residential properties. They used intervention analysis model to determine the impact of the obstruction of existing view from a new development on the value of the obstructed property. The authors estimated the adverse impact on the prices of the affected properties to be in the region of 8% from the start of the construction of the new development. They also concluded that the premium of a sea view is about 15.38% based on the average selling price.

Views are found to have substantial impact on property values in most studies although some studies have also reported insignificant impacts (Davies, 1974; Brown and Pollakowski, 1977; Correll et al., 1978; Paterson and Boyle, 2002). There is therefore no general consensus amongst these studies on whether views have a significant impact on prices.

2.1.3. About Fengshui

The Chinese traditionally believe that a person's well-being is governed by three types of luck that come from the heaven, the earth, and the individual himself or herself, respectively. Heaven luck, commonly referred to as fate, is beyond the control of humans and difficult to change. However, earth luck and human luck are within human control, and can be activated and altered by Fengshui wisdom (Bourassa and Peng, 1999).

Fengshui literally means wind and water, which are the elemental forces of the earth, and are believed to have hidden power to determine the course of events. Fengshui has its roots in the Tao, an ancient Chinese philosophy analyzing the environment and interpreting the “way of nature”. According to the Tao, there is order and balance in the world.

The practical tenets of Fengshui are a complex blend of logical reasoning, common-sense maxims, and oral tradition, some of which are no more substantial than superstitions. The practice of Fengshui incorporates ideas of geography, ecology, astrology, aesthetics, psychology and more, and it attempts to ensure a good life through site selection and the arrangement of objects on a site.

For centuries, Fengshui has influenced Chinese thinking, and the Chinese people have relied on Fengshui when designing cities, building homes, and burying their ancestors.

With the establishment of the People’s Republic in 1949, officials denounced Fengshui as a primitive superstition that should be abolished. Since then, Fengshui has fallen from favour in the land of its origin. However, in other places, like Hong Kong, Taiwan and Singapore, where there are large Chinese populations, Fengshui thrives as a fact of daily life. People rely on Fengshui to find or build a house that will bring the family health and prosperity. (Bourassa and Peng, 1999)

Numbers are highly significant to the practice of Fengshui because they are considered to be symbols that have special meaning and intangible forces. Bourassa and Peng (1999) focused on an area with a relatively high percentage of Chinese households in Auckland, New Zealand to investigate whether house values were affected by lucky and unlucky numbers. They believed that if a number sounds like something good, it is considered to be a good number. If it sounds like something bad, it is considered to be bad. According to this rule, Three, Six, Eight and Nine are considered to be lucky numbers, while Four is considered to be an unlucky one.

Chau, Ma, and Ho (2001) found that lucky house numbers (e.g. 8, 18 and 28) have significant positive hedonic prices in Hong Kong and were sold at significantly higher premiums during periods of property boom.

Tse and Love (2000), found that a cemetery view has a negative impact on a property's price in Hong Kong. This is because the view of a cemetery is regarded by the Chinese as inauspicious as it connotes death and is definitely bad feng shui (geomancy).

2.2. Application of computer technique in real estate and valuation research

The overall technological transformation of the computing industry has facilitated the widespread application of Geographical information system (GIS) and other IT tools in the real estate industry. GIS coupled to 3D visualization technology is an emerging tool for urban planning and landscape design applications. The utility of 3D software for realistically visualizing the built environment and proposed development scenarios is much advocated in the literature.

Research that has applied GIS directly to property valuation has been undertaken by Longley et al. (1993); Wyatt (1996). These studies have amply demonstrated the added value of the geographical display and analysis of property information. They discussed how GIS can be linked with computer assisted mass appraisal (CAMA) systems.

Sui, Chen and Zhu (2004) utilized 3D city models based spatial analysis, which would be more meaningful for urban designers. Noise environment, sunshine condition, heat environment, ventilation condition, and pollution condition could be analyzed. All kinds of urban planning information were organized and managed on unite database platform.

Viitanen et al (2005) discussed possibilities to utilize large laser scanner data sets in studies of real estate economics and environmental economics. The application areas to be discussed included monitoring land use, property valuation, and environmental impact assessment.

McCluskey et al (2000) examined the potential applicability of alternative locational modeling paradigms, in particularly utilizing the spatial characteristics of residential property values within surface response techniques.

As mentioned before, Yu and Chai (2005) applied GIS and 3-D modeling technique to quantify the view of Singapore residential properties. Other similar researches include Paterson and Boyle (2002).

Paterson and Boyle (2002) used GIS data to develop variables representing the visibility of surrounding land cover features in a hedonic model of residential housing markets. The visibility variables measured the percentage of the land visible overall within one kilometer of a property, as well as the percentage of visible land in each land use category. Four types of land use were examined: development, agriculture, forests and surface water. Three hedonic models are then estimated to determine if views affect property prices and further if omission of visibility variables leads to omitted variable biases. Results illustrate that the visibility measures are important determinants of price and their exclusion may lead to incorrect conclusions regarding the significance and signs of other environmental variables.

2.3. Application of the hedonic pricing model

2.3.1. General application of hedonic pricing model in the housing market

American scholar Lancaster (1966) first put forward a new consumer theory, which was expanded from the consumer theory of classical economics, also known as Lancaster preference theory. Lancaster argued that the consumer's preferences were exercised not based on the product themselves, but on their characteristics. Numerous studies applied this model to analyze the relationship between property attributes and prices (Gillard, 1981; Hughes and Sirmans, 1992).

Ridker and Henning (1967) were the pioneers who applied the hedonic price approach in residential properties. They investigated the relationship between air quality and property values, but it was Freeman (1979) who gave the first theoretical justification for the application of this technique to housing. Specifically, Freeman used the hedonic price equation to measure the marginal implicit prices and the willingness to pay for housing attributes, such as environmental quality.

The Hedonic pricing method employed in such studies typically used multiple regression techniques to relate property price details to the diverse characteristics of properties (Freeman 1993). Lake et al (2000a, 2000b) categorized those characteristics into four groups of variables. Structural variables relate to the direct characteristics of the property (e.g. age and size), while neighbourhood variables describe the quality of its surroundings (e.g. levels of unemployment). Accessibility variables define the ease with which amenities can be reached from the property (e.g. shops) and environmental characteristics include factors such as noise and indicators of the type and extent of land uses which can be seen from the property.

Structural attributes

In terms of structural attributes, lots of studies have found that the number of rooms/ bedrooms and the floor area are positively related to the house prices. (Li and Brown, 1980; Rodriguez and Sirmans, 1994). This is because buyers are willing to pay more for more space, especially functional space. For example, Garrod & Willis reported that an additional room increases a property's value by about 7 %, and an extra bathroom caused twice that premium. However, structural characteristics preferred by home buyers may not always be identical over time or cross nations. Kohlhase (1991) reported three hedonic house value equations in 1976, 1980 and 1985, in which coefficients of lot size and floor area were quite different.

Although structural quantity has been well researched, there has been relatively little research on structural quality due to the difficulty in measuring the quality of the properties objectively (Kain & Quigley, 1970; Morris, Woods, & Jacobson, 1972). Kain and Quigley (1970) used measures such as exterior structure, condition of floors, windows, walls, and levels of housekeeping to investigate the impact of housing quality on housing prices. These quality features were found to have as much effect on the price of housing as the number of rooms, number of bathrooms, and lot size. Ooi (2005) considered developer's profile in his study, which was represented by the prior experience, ranking by market share and listing status of the developer.

Neighborhood

As to neighbourhood attributes, in previous research, they have been classified as: Socio-economic variables, local government or municipal services (e.g. schools or hospitals) and externalities such as crime rates and shopping centres.

For example, Clauretie & Neill (2000) found that attributes of schools were more highly valued by local residents than either crime or environmental quality measures within the community in Fresno, California. Steve Gibbons (2003) showed that home-owners in England and Wales were prepared to pay a substantial premium to avoid educationally poor neighbourhoods. An increase of 1 percent in the proportion of higher-educated residents in a community, relative to the regional mean, increased prices by 0.24 percent.

Accessibility

Accessibility also remains an important feature for urban properties. Earlier attempts to account for it by using transportation cost focused on a limited number of factors, especially a CBD oriented interaction related to employment and shopping.

Dewees (1976) analysed the relationship between travel costs by railway and residential property values. Dewees found that a subway station increased the site rent perpendicular to the facility within a one-third mile to the station. Consistent with these conclusions, Grass (1992) later found a direct relationship between the distance of the newly opened metro and residential property values. However, there are studies which have also found insignificant effects (Gatzlaff and Smith 1993).

Most recently, Debrezio et al (2006) analyzed the impact of railway accessibility on residential house prices in Dutch. They found that dwellings very close to a station were on average about 25% more expensive than dwellings at a distance of 15 kilometres or more. A doubling of frequency leads to an increase of house values of about 2.5%, ranging from 3.5% for houses close to the station to 1.3% for houses far away. They also found a negative effect of distance to railways, probably due to noise effects.

Special focus on environmental factors

As environmental concerns become more important at the local, regional, and global level, more attention must be paid to the development of sustainable buildings. We classified our research focus- orientation into the category of environmental factors, since it affects the comfort of residents. Literatures about those effects are reviewed as follows.

Environmental effects on housing price, such as air quality, noise and weather condition, are relevant to the externalities of properties. Households demand good externalities on the human health/comfort and would like to pay some premiums for the pleasant environment.

Chay and Greenstone (2004) exploited the structure of the Clean Air Act Amendments (CAAAs) to provide evidence on the capitalization of air quality into housing values. They reported that the improvements in air quality induced by the mid-1970s TSPs nonattainment designation are associated with a $45 billion aggregate increase in housing values in nonattainment counties between 1970 and 1980.

Cohen and Coughlin (2005) focused on the effects of proximity and noise on housing prices in neighborhoods near Hartsfield-Jackson Atlanta International Airport. They found that proximity to the Atlanta airport was related positively to housing prices and that airport-related noise was associated with lower prices.

Hoch and Drake (1974) developed a general multi-market hedonic model to study wages, housing prices and location-specific amenities. Six variables for climate conditions were sunshine, precipitation, humidity, windspeed, heating/cooling degree days, etc. Results showed that much sunshine is one of amenities while humidity was found to be a disamenity.

Maddison and Bigano (2003) use Italian data and hedonic methods to document the capitalization of climate into Italian real estate price. It was a considerable empirical support for the hypothesis that information on the amenity value of climate is contained in the market for housing and labor in Italy.

Arsenio et al (2006) analyzed the road traffic noise and they stated that "the inclusion of view and exposure to sunlight made the choice experiment realistic, since these would vary between apartments and they features as attributes in information published by estate agents in Lisbon who regard them as decision making variables."

2.3.2. Application of the hedonic pricing model in China

Because of the difficulty of getting transaction data in mainland China, there have been very few empirical studies using hedonic pricing model. Recently, housing market in China is more and more active and transparent, which facilitates the application of hedonic model.

Ma and Li (2003) analyzed house price and its determinations in Beijing based on hedonic model. They considered 9 independent variables (Location, number of storey, greening ratio, property management fee, car park rental, decoration of kitchen/toilet, water supply, communication and property status) first and found only 3 variables- location, property management fee and inner decoration level, are significant.

Wen, Jia and Guo (2005) chose 18 characteristics as independent variables and set up a linear hedonic price model for Hangzhou City. They found that floor area and distance to West Lake have much more influence on property prices, while housing age and orientation were not statistically significant.

Yang (2001) examined the implicit prices of housing characteristics concerning the physical structure, location, environment and the risk of construction quality in China. The results indicated that consumers had different preferences for choosing residences in the different parts of Beijing and the marginal price of public facilities was negative.

2.4. Summary

From the literature review, we show that sunlight and view, determined by the house orientation, have a significant impact on human health, comfort and energy saving. Designers try to utilize the advantage of sunlight but avoid high energy consumption at the same time. Orientation, as an attribute of residential property, will influence the demand of home buyer, and hence, the house price.

However, there is no study linking the orientation, especially sunlight of a housing unit, with house price distinctly. The reason may lie in the difficulty in measuring sunlight. Such a problem can be solved using IT tools and 3D modeling technique. We use a sunlight analysis software to calculate the sunlight duration of each hosing unit and incorporate it into the hedonic pricing model. By doing so, we could analyze the effect of orientation on housing price in different location, say Beijing and Singapore.

Chapter 3   Data and Methodology

3.1. Study area

The number and nature of influences on house prices are large and heterogeneous. In order to focus on the factors relative to orientation, we choose samples with similar location and neighborhood characteristics.

For the purpose of this study, we choose transaction prices of a large residential area: Hillview district in Singapore and Chaoyang Park area in Beijing. Such samples are ideally suited to the purpose of this research because both are large metropolitan areas with a large number of transaction, households are in the middle income class, and building qualities are more or less the same.

We analyze multiple factors affecting property prices: size; floor level; orientation etc. Orientation determines the sunlight received in a housing unit and we expect that much sunlight is preferred by Beijing households than Singaporean. The results of estimations based on the models presented here describe how the importance of those attributes is related to house prices.

3.1.1. Study area in Beijing

China began its urban housing system reform in 1980 (subsequent to the famous

Deng Xiaoping speech on housing reform in April). In March 1998, Chinese Premier Zhu Rongji introduced a package of reforms that included a series of housing reforms -intended to stimulate the domestic economy. He declared that subsidized housing traditionally available to Chinese workers would be phased out and that workers would be encouraged to buy their own homes or pay rent close to real market prices. The reforms called for workers to use their savings, along with the one-time housing subsidies they receive, to purchase their own houses. The government announced in August 1999 that all vacant residential housing units built after January 1, 1999 were to be sold, not allocated. Since then, the private housing market has experienced tremendous growth.

It was reported at the January 9, 2001 National Housing Reform Conference, that over 80 percent of the allocated public housing in China have already been sold to workers or employees. A new property ownership structure dominated by private ownership along with other types of ownership forms (state ownership and collective ownership) has taken root in China.

Beijing, as the capital and cultural, political center of China, has experienced a rapid economic development through past 20 years. Its total area is 16,808 sq.km, in which the urban planning area is 1,042 sq.km. Total population is over 15 million. Beijing is located near Lat 39.9 deg N and Long 116.3 deg E.

Lying in the northern part of North China Plain, Beijing has a continental monsoon climate with four distinct seasons. Spring and autumn are short while winter and summer are long. December is the coldest month with an average temperature of -2.9^{o}C while July is the hottest month with an average temperature of 27.5^{o}C (from statistics of Beijing Meteordogical Bureau, source year is 2002).

As Beijing grows, spurred by China’s entry to the WTO and hosting of the 2008 Olympic Games, more foreign companies invested in this city and bring more expatriate staff. These expatriates are the key contributors to demand for residential property especially in the high-end sectors.

Occupying 470.8 square kilometres (sq.km) of land and with a population of 2.52 million, Chaoyang district is the largest and densest district in Beijing. Office towers, hotels, first-class apartments and multiple service organizations involved in finance, IT and intermediary service industries make Chaoyang Beijing's biggest and most rapidly developing economic area. Chaoyang’s green coverage is 41 percent of its total area, accounting for one-half of the total green areas in Beijing.

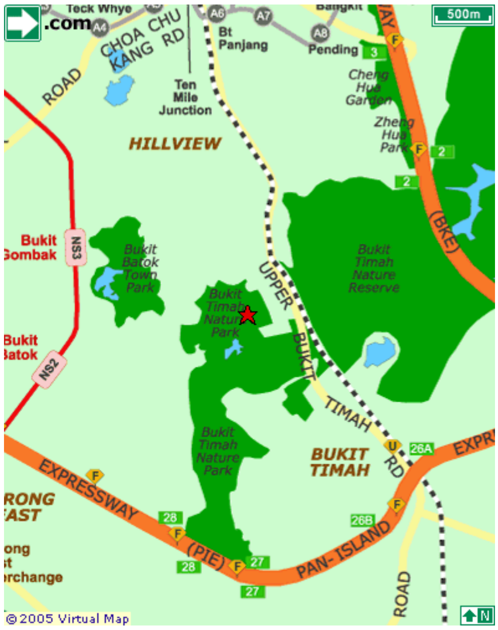
Those attributes make residential property prices in Chaoyang district much higher than the average level in Beijing. Especially in the area adjacent to Chaoyang Park, Which is located in east Fourth Ring Road of Beijing, is the largest urban park in Asia. The planned total area of this park is 320 hectares, including 67-hectare water area and 253-hectare land area. Rate of green land in this park exceeds 75%. In Beijing Overall Urban Plan Program, Chao Yang Park is one of key projects. Over 20 residential projects are located around Chao Yang Park, some of which enjoy pleasant parkview. Because of data availability, transaction data used in this dissertation are all from the project A (Exact name is omitted for confidential reason), which are retrieved from real estate consulting company and developer.

3.1.2. Study area in Singapore

Singapore lies just north of the Equator near Lat 1.5 deg N and Long 104 deg E. Its climate is characterized by uniform temperature and pressure, high humidity and abundant rainfall. Its temperature is with only slight variations between the average maximum of 31 degrees Celsius and minimum of 23 degrees Celsius. Under such circumstances, lower temperature and better windy condition are preferred in Singapore. Less sunlight especially in afternoon often reduces air conditioning energy requirements because the internal cooling load is reduced.

In Singapore, the area of analysis will be limited to the area adjacent to Hillview Road, which is located in the district 21 of Singapore. There are a large number of condominium projects within this area. Nearby landscape includes Bukit Timah Nature Reserve Bukit Batok Nature Park, and Bukit Batok Town Park.

Figure 3-1 Map of study area in Singapore



(Source: www.streetdirectory.com.sg)

The Bukit Timah Nature Reserve is the only primary rainforest that remains in modern day Singapore. The peak of Bukit Timah is Singapore's highest ground at about 164 metres above sea level. The forest was never extensively cleared for cultivation and shelters a vast variety of plants. Bukit Batok Town Park is known as Little Guilin or Xiao Guilin among the locals, this park looks similar to that of Guilin in China - a granite rock sitting within a lake. Bukit Batok Nature Park was developed on an abandoned quarry site in 1988. Several look-out points, some reaching more than 10 storeys high, provide breathtaking views. Sizes of those three parks are 164, 42 and 36 hectares respectively.

Subject projects are located along the Hillview Avenue and Hume Avenue. Some housing units have nature view of Bukit Timah hill or park. Large areas of green vegetation offer residents a pleasant visual enjoyment. Basically, projects in this area are high-rise condominiums. Housing units are around the lift in the center, so units in the same story have different orientation.

In summary, the reasons why we choose such study areas lie in that those areas possess sufficient private properties, high-rise buildings with different house orientation and the existence of Parkview.

3.1.3. Project Information

Our focus is on condominium properties in those districts. Most projects in study area are freehold, with a few 99 years leasehold in Singapore. In Beijing, all residential properties have 70 years leasehold. They are relatively new developments, completed during 2003 to 2006. Table 3-1 gives the elementary characteristics of projects.

Table 3-1 Project descriptions

No.	Project name	Address	Tenure	District	TOP	No. of units	No. of transaction
1	Hillview Regency	226 Bukit Batok East Ave 2	99 years	Singapore21	2006	572	385
2	The Petals	85,87,89,91,93,95,97 Hillview Avenue	Freehold	Singapore21	2003	270	232
3	Hillington Green	45 – 59 Hillview Avenue	Freehold	Singapore21	2004	522	467
4	A	Chaoyang district	70 years	Beijing	2005	948	831

3.2. Data

In order to utilize the hedonic pricing model, we must obtain transaction price and specific property characteristics of each housing unit.

3.2.1. Transaction data

In Singapore, transaction data are extracted from the Urban Redevelopment Authority's (URA) Real Estate Information System (REALIS). Data in Beijing are obtained from a real estate consulting company. For each observation, data include transacted price, project type, tenure, planning region, address, type of sale, floor area, contract data and unit price. All those developments are pre-sold by developers, i.e., before the start of completion to take advantage of the progress payments which help to reduce financing costs. The total number of transaction data is 1084 in Singapore and 831 in Beijing (pre-sale data).

3.2.2. Site plan and floor plan

To determine the orientation of each housing unit, site plan, floor plan and location of surrounding buildings are necessary. Such drawings are obtained in the websites of developers or real estate agencies. Supplementary site inspection is proceeded to confirm the information. Site plan drawings are shown in Appendix figure 2.

3.3. Methodology

A hedonic pricing model is used to estimate the impact of several variables on the house prices. SUNLIGHT 2.0, which is a sunlight analysis software developed by China Institute of Building Engineering Software is employed to get the orientation variables that we are focusing on.

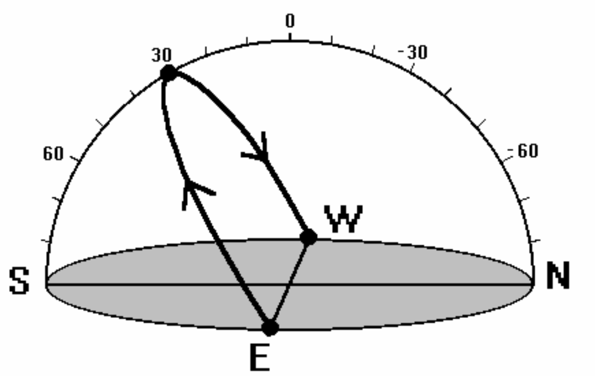
3.3.1. Orientation Variables

There are three types of variables pertaining to orientation: sunlight, view and fengshui variables. In this study, we pay much attention on the sunlight variables.

3.3.1.1. Sunlight variables

Weather on earth is due to sunlight. The intensity and amount of sunlight received varies with time of the day, day of the year, and geographical latitude. Variations of sunlight lead to temperature and density differences in both atmosphere and sea, and these differences in turn produce the winds and ocean currents. Figure 3-2 is a sketch map of the sun path.

Figure 3-2 Sketch map of the sun path



We do not choose direction dummy to reflect sunlight, like EAST, SOUTH, WEST and NORTH. The reason is that sunlight would be blocked by surrounding buildings, we must construct a model to consider both direction of subject building and the block effect of adjacent buildings. Another reason is that sunlight will change with the floor level, which means the model must be of 3 dimensions. Housing units with same direction but at different floor level may have different sunlight duration.

Since house will conserve energy obtained in daytime, release it at night and master bedroom is the room where residents spend most time in one day, sunlight in that room greatly affects the utility and comfort of households. Thus, we choose the sunlight duration within the master bedroom in a housing unit in sunlight analysis.

Firstly, we judge whether a housing unit can receive sunlight on a specific day, then construct a continuous variable to reflect the sunlight duration. We expect that in Beijing, much sunlight, especially during winter day, has a premium on house price. While in Singapore, much sunlight is not preferred, particularly afternoon sun.

3.3.1.2. Sunlight analysis

In sunlight analysis, we need to calculate the position of sun in relation to the location of subject building. The sun's position in the sky is expressed by altitude angle h and azimuth angle α, which will change with geographical latitude ψ, declination δ and hour angle Ω (Shown in figure 3-3). It can be calculated using following formulas:

Altitude angle $\sin h = \sin\psi \times \sin\delta + \cos\psi \times \cos\delta \times \cos\Omega$

Azimuth angle $\cos\alpha = (\sin h \times \sin\psi - \sin\delta)/\cosh \times \cos\psi$

Figure 3-3 Position of the sun

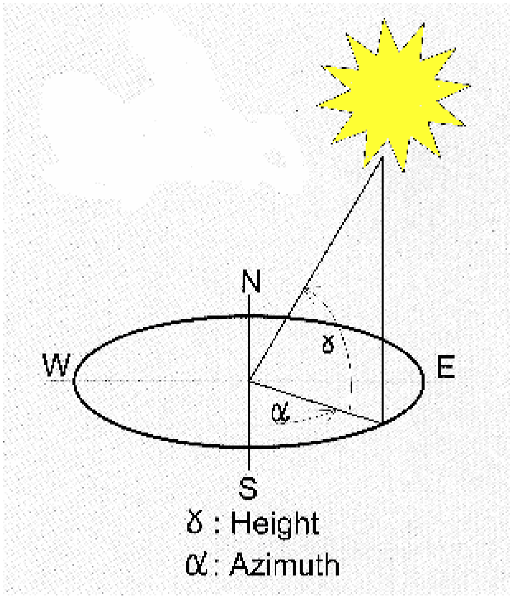
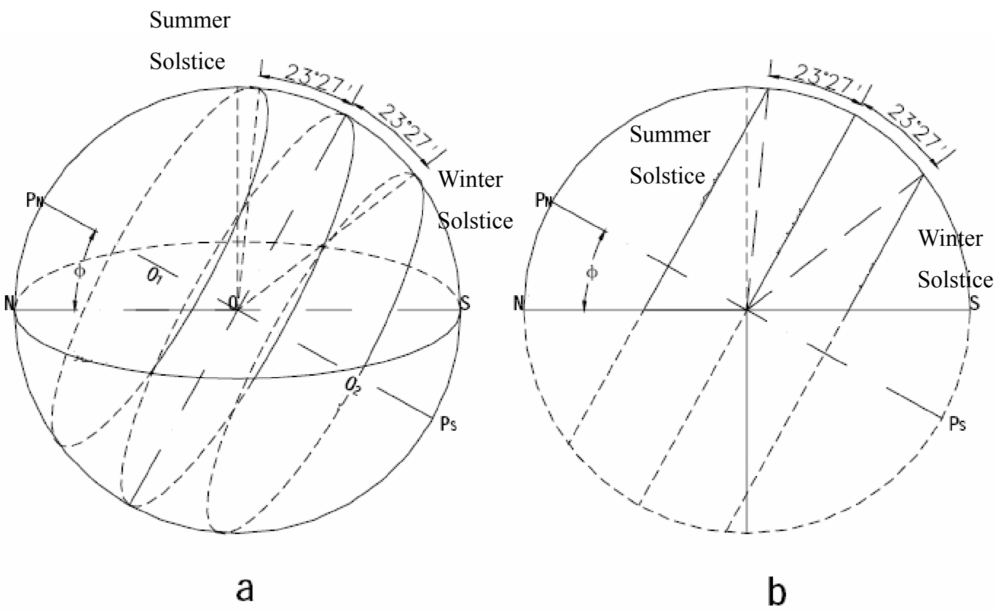


Figure 3-4 shows the movement tracking of sun. Explanations of parameters are in table 3-2.

Figure 3-4 Movement tracking of sun



(Source: Help file of software SUNLIGHT 2.0.)

Note:

Declination +23°27’ On June 21 or 22 (Summer solstice);

Declination -23°27’ On Dec. 22 or 23 (Winter solstice).

Table 3-2 Explanations of parameters

Parameter	Symbol	Description
Sun position	h, α	According to the relative movement of sun and earth, observe the sun track in the sky from earth. Represented by h and α.
Altitude angle	h	Describes how high the sun appears in the sky. It is the angle between the line to the centre of the sun and the horizontal plane. When the sun is on the horizon, the solar altitude is 0°; when directly overhead 90°
Azimuth angle	α	The reference plane for the solar azimuth is the south and the point on the horizon directly below the sun. By convention, it is negative before noon and positive after noon. The azimuth is referenced to due south in the Northern hemisphere.
Geographical Latitude	ψ	The latitude of a point on the earth's surface is its angular distance from the equator, measured on the curved surface of the earth.
Declination	δ	The angle between the ecliptic and the plane of the earth's equator. The Declination angle is 23.5° during the Northern Summer Solstice, and –23.5° during the Southern Summer Solstice.
Hour angle	Ω	The Hour Angle is the angular distance that the earth has rotated in a day. It is equal to 15 degrees multiplied by the number of hours from local solar noon. This is based on the nominal time, 24 hours, required for the earth to rotate once i.e. 360 degrees.

After obtaining altitude and azimuth angle, we analyze whether a subject building is being blocked by surrounding buildings using projection theory. With the development of computer technique, such functions can be fulfilled by professional sunlight analysis software.

3.3.1.3. Application of SUNLIGHT 2.0

Sunlight analysis software constructs entire mathematical models to consider the relationship between the earth and sun. It is able to calculate the sunlight duration at any position in a subject building. Conical surface of sunlight can be determined by following formulas:

$$x = \frac{L * \left[\sin^2 \psi * \sin \delta + \sin \psi * \cos \psi * \cos \delta * \cos t - \sin \delta\right]}{\cos \psi}$$

$$y = L * \cos \delta * \sin t$$

$$z = L * \left[\sin \psi * \sin \delta + \cos \psi * \cos \delta * \cos t\right]$$

Where,

x, y and z represent the coordinate of any point on the conical surface;

L=H * tgh, H is the height of subject building;

t is time;

Other variables see Table 3-2.

Then we use formulas to represent a surface of building, relate it with conical surface of sunlight. The solution of those function groups stands for the sunlight duration of a specific location in a building surface.

Input variables include longitude and latitude of study area, plan profiles of subject buildings, building heights (storey heights*number of stories), window sizes (width* heights) in master bedroom, 3D models of surrounding buildings. Table 3-3 explains input variables in detail.

Table 3-3 Descriptions of input variables for sunlight analysis

Input	Beijing	Singapore
Longitude	104^0 E	116.3^0 E
Latitude	1.5^0 N	39.9^0 N
Building Heights	Storey heights*number of stories	
Storey Heights	Supposed to be 3 m	3.4 m in Parkview Avenue
Number of stories	Obtained from project documents	
Window sizes	Obtained from project documents	
Surroundings	To consider the blocking effect of surrounding buildings; Gotten from the map of study area; Include the buildings in the same development since buildings outside are too far to affect subject building	

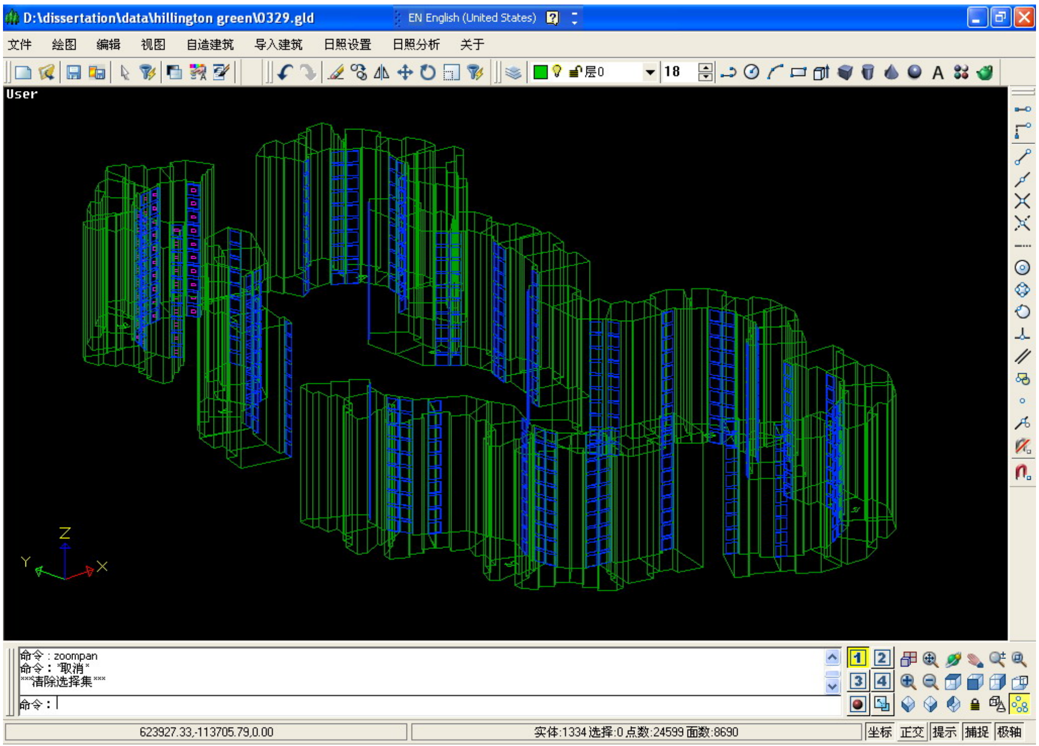
Sunlight duration varies with time, we select winter and summer solstice as the study days because there appear shortest and longest sunlight duration in those two days. On winter solstice (22^{nd}, December), sun rises at 06:03 am and is down at 17:58 pm in Singapore time. In terms of summer solstice (22^{nd}, June), sun appears from 05:58 to 18:01. Total sunlight durations are 715 minutes and 723 minutes respectively. Sunlight duration is different in Beijing. Details are shown in table 3-4.

Table 3-4 Sunlight duration in Beijing and Singapore

		Beijing	Singapore
Winter	Sunrise	07:26 am	06:03 am
	Sunset	16:37 pm	17:58 pm
	Duration	551 minutes	715 minutes
Summer	Sunrise	04:37 am	05:58 am
	Sunset	19:22 pm	18:01 pm
	Duration	885 minutes	723 minutes

In this study, we apply SUNLIGHT 2.0 developed by the Institute of Building Engineering Software (this software has been certified by the Ministry of Construction, China) to calculate the sunlight duration in master bedroom of each housing unit. A sample of 3-D models used in this sunlight analysis is given in Figure 3-5 and sample output result is shown in Table 3-5.

Figure 3-5 3D model in the Sunlight analysis (Hillington Green in Singapore)



(Note: Blue rectangular represents window in master bedroom.)

Table 3-5 Sample output table in sunlight analysis

No. of window	Location of study point	Dimension of window	Elevation of window	Orientation	Total sunlight duration	Largest continuous duration	Sunlight period
C19-5-3	170014,-71352.7,13600.0	4000*2400	13600.0	South-east 24^0	4:57	4:57	9:4--14:1
C19-25-3	170014,-71352.7,81600.0	4000*2400	81600.0	South-east 24^0	5:10	5:10	8:51--14:1
C19-27-3	170014,-71352.7,88400.0	4000*2400	88400.0	South-east 24^0	5:30	5:30	8:31--14:1
C19-28-3	170014,-71352.7,91800.0	4000*2400	91800.0	South-east 24^0	5:46	5:46	8:15--14:1
C19-29-3	170014,-71352.7,95200.0	4000*2400	95200.0	South-east 24^0	6:22	6:22	7:39--14:1
C19-30-3	170014,-71352.7,98600.0	4000*2400	98600.0	South-east 24^0	6:59	6:59	7:2--14:1
C19-31-3	170014,-71352.7,102000.0	4000*2400	102000.0	South-east 24^0	7:55	7:55	6:6--14:1
C19-21-1	130663,-77379.1,68000.0	2700*2400	68000.0	South-west 66^0	5:49	5:49	11:29--17:18
C19-22-1	130663,-77379.1,71400.0	2700*2400	71400.0	South-west 66^0	5:56	5:56	11:29--17:25
C19-23-1	130663,-77379.1,74800.0	2700*2400	74800.0	South-west 66^0	6:4	6:4	11:29--17:33
C19-24-1	130663,-77379.1,78200.0	2700*2400	78200.0	South-west 66^0	6:13	6:13	11:29--17:42
C19-25-1	130663,-77379.1,81600.0	2700*2400	81600.0	South-west 66^0	6:22	6:22	11:29--17:51
C19-26-1	130663,-77379.1,85000.0	2700*2400	85000.0	South-west 66^0	6:33	6:33	11:29--18:2

3.3.1.4. View

We incorporate dummy variables representing parkview and poolview into the hedonic function. View variables are obtained according to maps of study areas. Details are shown in table 3-6.

Table 3-6 Descriptions of view variables

Variable	Beijing	Singapore
Parkview	Equals 1 if the window of living room faces to Chan Yang Park	Equals 1 if the window of living room faces to Bukit Timah Nature Reserve or Bukit Batok Town Park.
Poolview	Nil	Equals 1 if the window of living room faces to the swimming pool.

3.3.1.5. Fengshui factors

Fengshui may play a role when home buyers choose properties since there is high percentage of Chinese descendent in Singapore. According to Fengshui, south-faced houses are usually thought better than others. We use dummy variable SOUTH to reflect this factor.

Some previous studies investigated whether house values were affected by lucky and unlucky numbers to consider the effect of Fengshui. In this study, we do a similar analysis on the number of floor level. We expect that number of 4 has negative effect while number 8 is preferred by home buyers. Variable LEVEL8 equals 1 if the last digit of the floor level number is 8 and 0 otherwise. LEVEL4 equals 1 if the last digit of the floor level number is 4.

3.3.2. The hedonic pricing model

In this study, all projects are in the same neighborhood- Hillview district in Singapore/ ChaoYang Park area in Beijing, so the location effect can be eliminated from the analysis. Our focus is on orientation variables, including sunlight duration and visibility. We use the hedonic pricing model below:

$$\text{LogP} = \beta_0 + \Sigma\, \beta_1 X + \Sigma\, \beta_2 Y + \Sigma\, Z_0$$

Where P is the transacted price of property, X being the housing characteristics, Y being the purchaser's characteristics, Z being the series of time dummies, β_0, β_1, β

$_2$ and β_3 being the estimated coefficient parameters. Table 3-7 gives descriptions of variables.

Table 3-7 Descriptions of variables

Variable	Description
Price	Continuous dependent variable representing selling price
Lnprice	Continuous dependent variable representing the natural log of selling price
Area	Continuous dependent variable representing the floor area of the individual unit
Storey	Continuous dependent variable representing the floor level of the individual unit
New	Dummy variable equals 1 if the transaction is a developer sale
Tenure	Dummy variable equals 1 if the property is freehold or 999 years leasehold
Q1-Q22	Dummy variable to control temporal market effect, equals 1 if the transaction takes place in the particular quarter. Q1=2005Q3, Q2=2005Q2 and so on, Q22=2000Q2.
Parkview	Dummy variable equals 1 if adjacent park is visible from a housing unit
Poolview	Dummy variable equals 1 if the swimming pool is visible from a housing unit
WINTER (Dummy)	Dummy variable equals 1 if a housing unit can receive sunlight during winter solstice day
SUMMER (Dummy)	Dummy variable equals 1 if a housing unit can receive sunlight during summer solstice day
WINTER	Sunlight duration that a master bedroom can receive during winter solstice day (in min.)
SUMMER	Sunlight duration that a master bedroom can receive during summer solstice day (in min.)
WINTERAM (Dummy)	Dummy variable equals 1 if a housing unit can receive sunlight before 12 p.m. in winter solstice day
WINTERPM (Dummy)	Dummy variable equals 1 if a housing unit can receive sunlight after 12 p.m. in winter solstice day
WINTERAM	Sunlight duration hour that a master bedroom can receive before 12 p.m. in winter solstice day
WINTERPM	Sunlight duration hour that a master bedroom can receive after 12 p.m. in winter solstice day
SOUTH	Dummy variable equals 1 if the living room in a housing unit faces south
LEVEL4	Dummy variable equals 1 if the last digit of the floor level number is 4
LEVEL8	Dummy variable equals 1 if the last digit of the floor level number is 8
PETALS	Dummy variable equals 1 if the housing unit is in “The Petals”
HILLVIEW	Dummy variable equals 1 if the housing unit is in “Hillview Regency”
HILLINGTON	Dummy variable equals 1 if the housing unit is in “Hillington Green”

Chapter 4 Findings on the Impact of Orientation

4.1. Introduction

In this chapter, we test whether 3D sunlight analysis software could be applied and whether orientation has significant impact on property values in Singapore. We calculate the sunlight duration of each housing unit and incorporated it into the hedonic pricing model.

4.2. Descriptive statistics

Table 4-1 shows the general statistics of selected observations in Singapore. Average house value is S$736,842 (US$ 465,648). Among structural characteristic variables, average floor area is 123 sqm and average storey of selected developments is 8. 79% of transactions are developer's sale, 64% of housing units possess freehold or 999 years leasehold tenure.

Among all observations, 72% of housing units can receive sunlight on winter solstices day, while 51% of all units have sunlight on the morning of winter solstices day. Average sunlight duration is 255 minutes and 155 minutes during the winter and summer solstices respectively.

Table 4-1 Descriptive statistics

Variable	Singapore		
	Min	Mean	Max
Price (US$)	240160	465648	969185
Lnprice	12.3891	13.0512	13.7842
Area (sqm)	84	123	409
Storey	1	8	25
New	0	0.79	1
Tenure	0	0.64	1
Parkview	0	0.19	1
Poolview	0	0.14	1
SOUTH	0	0.14	1
WINTER(Dummy)	0	0.72	1
SUMMER(Dummy)	0	0.52	1
WINTERAM(Dummy)	0	0.51	1
WINTERPM(Dummy)	0	0.62	1
WINTER(Min)	0	255	715
SUMMER(Min)	0	155	362
WINTERAM(Min)	0	126	356
WINTERPM(Min)	0	130	359
LEVEL4	0	0.11	1
LEVEL8	0	0.11	1

4.3. Regression results of the hedonic pricing model

A semi-logarithmic function was selected as the appropriate functional form since it shows a better fitness of data. Estimated coefficients from semi-log equations represent growth rates, and prices are determined relative to the amount of explanatory characteristic present. An advantage of semi-log form is the ability to clearly interpret coefficients on dummy variables (Kennedy, 1981). In order to test whether sunlight analysis tool can be applied in this study, we first use data in Singapore to run the regression.

Results of the hedonic pricing model using log-linear model are presented in table 4-2 to table 4-5. In the first set of models (models 1 and 2), we analyze the impact of orientation of housing units in terms of whether it allows them to receive sunlight during the winter and summer solstices. We further analyze the impact if a housing unit is able to receive sunlight during the morning or afternoon on the winter solstice.

In the second set of models (models 3 and 4) we analyze the sunlight duration (in minutes) of the master bedroom of housing unit received during the winter solstice and summer solstice. We then further define the sunlight duration received specifically during the winter solstice, which is divided into morning and afternoon, i.e., the amount of sunlight (in minutes) on the winter solstice in the morning as well as in the afternoon. We want to test whether sunlight in the morning or afternoon has a different impact on property price. The reason why we choose winter solstice day is that this is the shortest day of the year in the northern hemisphere, particularly, for the temperate countries.

In general, the adjusted R^2 of regressions are quite high. White's(1980) test revealed that residuals exhibited heteroskedasticity (result of White Heteroskedasticity Test is shown in Appendix table 1). The null hypothesis of homoskedasticity was rejected at 1% level. Accordingly, we use White's method to adjust for heteroskedasticity. Since the dependent variable is in log scale, coefficients should be interpreted as a percentage change in property prices, given a unit change in an independent variable. A detailed discussion of results is given below.

Most of coefficients of the control variables show expected sign and are consistent with previous results. Structural variables like floor area and floor level are positive and significant at 1% level.

View of swimming pool is much preferred, while Parkview is negative but not very significant in most models. The reason may lies in that in Hillview district, there are plenty of trees and green belts besides natural parks. All households can enjoy view of vegetation and access to parks quite easily. Parkview in the living room is not regarded as valuable attribute. Housing units with freehold tenure or 999 years leasehold are more valuable as expected.

Our focus is on sunlight variables, which are analyzed in terms of two sets of models: models using dummy variables and using continuous variables.

4.3.1. Using dummy variables

In model 1, WINTER(Dummy) is negatively significant in Singapore. In Singapore, housing unit (master bedroom) having sunlight during winter solstice has a drop of

3.12% from the average price. SUMMER(Dummy) variable is, however, insignificant in the regression, therefore we further analyze the sunlight during winter solstices in terms of morning and afternoon respectively. In model 2, WINTERAM(Dummy) and WINTERPM(Dummy) are all negative and significant.

Table 4-2 Regression results of model 1 (using dummy variables)

Variable	Model 1	
	Coefficient	Std. Error
Area	0.004629***	0.000406
Storey	0.010901***	0.000449
New	0.022908***	0.008244
Tenure	0.339497***	0.018343
Parkview	-0.018934***	0.006993
Poolview	0.034037***	0.005784
WINTER(Dummy)	-0.031745***	0.005599
SUMMER(Dummy)	0.003529	0.004993
No. of Observations	1084	
Adj. R-squared	0.9484	
F-statistic	664.02	

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Coefficients of constant and time dummies are not listed.

Table 4-3 Regression results of model 2 (using dummy variables)

Variable	Model 2	
	Coefficient	Std. Error
Area	0.004617***	0.000404
Storey	0.010946***	0.000441
New	0.024323***	0.008268
Tenure	0.341531***	0.018564
Parkview	-0.012081*	0.006818
Poolview	0.033248***	0.005741
WINTERAM(Dummy)	-0.025993***	0.004623
WINTERPM(Dummy)	-0.010986**	0.004363
No. of Observations	1084	
Adj. R-squared	0.9483	
F-statistic	658.98	

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Coefficients of constant and time dummies are not listed.

4.3.2. Using continuous variables

Although model 1 and model 2 get significant results, we want to apply continuous variables instead of dummies to quantify sunlight of each housing unit. WINTER, SUMMER, WINTERAM and WINTERPM are incorporated into the hedonic pricing model.

Similarly, in table 4-4, we find that in Singapore, sunlight duration in winter has a negative and significant effect on house price. For an additional hour of sunlight during the winter solstice, houses would cost 0.49% less than the average selling price. The longer is the sunlight duration, the lower the house price.

Table 4-4 Regression results of model 3 (using continuous variables)

Variable	Model 3	
	Coefficient	Std. Error
Area	0.004654***	0.000406
Storey	0.011109***	0.000432
New	0.023698***	0.008258
Tenure	0.341195***	0.018198
Parkview	-0.010381	0.006992
Poolview	0.033596***	0.005772
WINTER	-8.12E-05***	1.08E-05
SUMMER	-1.44E-05	1.25E-05
No. of Observations	1084	
Adj. R-squared	0.9496	
F-statistic	680.37	

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Coefficients of constant and time dummies are not listed.

The sunlight duration on the morning and afternoon of the winter solstice are also negative and significant. The coefficient for WINTERPM reflects a greater diminution in value implying that houses with afternoon sun are less preferred (-0.57% against -0.40%). This finding is consistent with our expectation and proves that afternoon sun dampens property price more severely.

From the results above, sunlight duration is proved to be a significant variable in the hedonic pricing model, house orientation is quantified by using sunlight analysis software.

Table 4-5 Regression results of model 4 (using continuous variables)

Variable	Model 4	
	Coefficient	Std. Error
Area	0.004662***	0.000405
Storey	0.011122***	0.000428
New	0.024312***	0.008176
Tenure	0.341397***	0.018182
Parkview	-0.012797*	0.007143
Poolview	0.032837***	0.005602
WINTERAM	-6.67E-05***	1.45E-05
WINTERPM	-9.53E-05***	1.44E-05
No. of Observations	1084	
Adj. R-squared	0.9496	
F-statistic	680.55	

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Coefficients of constant and time dummies are not listed.

Considering the effect of Fenghsui, we add variable SOUTH into previous model 3 and model 4. Results are shown in table 4-6 and 4-7. SOUTH proves to be significantly positive although coefficients of sunlight variables are still significant as before. We can conclude that besides sunlight and view, south facing houses are more preferred by households. This may be attributed to the influence of Fengshui.

Table 4-6 Regression results of model 5 (Incorporating SOUTH)

Variable	Model 5	
	Coefficient	Std. Error
Area	0.004660***	0.000406
Storey	0.011161***	0.000431
New	0.022470***	0.008430
Tenure	0.338161***	0.018241
Parkview	-0.011488	0.007015
Poolview	0.032802***	0.005810
WINTER	-9.36E-05***	1.07E-05
SUMMER	1.76E-07	1.33E-05
SOUTH	0.016971**	0.007687
No. of Observations	1084	
Adj. R-squared	0.9498	
F-statistic	660.76	

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Coefficients of constant and time dummies are not listed.

Among those six models, model 6 reveals the best fitness of data. Adjusted R^2 is 0.9499 and all explanatory variables show expected sign. According to model 6, for an additional hour on the afternoon of the winter solstice, house will have a drop of 0.66% from the average price. Unit facing south costs 1.85% more than the average selling price.

Table 4-7 Regression results of model 6 (Incorporating SOUTH)

Variable	Model 6	
	Coefficient	Std. Error
Area	0.004659***	0.000404
Storey	0.011202***	0.000430
New	0.021799**	0.008445
Tenure	0.338276***	0.018103
Parkview	-0.016130**	0.007321
Poolview	0.033522***	0.005540
WINTERAM	-7.46E-05	1.45E-05
WINTERPM	-0.000110***	1.46E-05
SOUTH	0.018296**	0.007160
No. of Observations	1084	
Adj. R-squared	0.9499	
F-statistic	662.30	

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Coefficients of constant and time dummies are not listed.

We also incorporate variables of LEVEL4 and LEVEL8 into the hedonic models to test the significance of number of floor level. Regression results dos not show any expected signs of coefficients.

4.4. Summary

Using 3D sunlight analysis software, we successfully construct sunlight variables and incorporate them into the traditional hedonic pricing model. Results show that sunlight has significant impact on house value. Specifically, house with sunlight during the winter solstice has a drop of 3.12% from the average selling price.

We apply two sets of models and find that models using continuous sunlight variables have superiority since we can quantify the orientation of each housing unit. For an additional hour of sunlight during the winter solstice, houses would cost 0.49% less than the average price. Subjective judgment on house orientation can be eliminated by using such models. Afternoon sun dampens property value more severely as expected.

In the next chapter, we do a comparative analysis between Beijing and Singapore. We expect that orientation plays different role in those two locations.

Chapter 5 Comparative Analysis between Beijing and Singapore

5.1. Introduction

In this chapter, we make a comparative analysis between Beijing and Singapore. We compare price determinants in those two cities with particular focus on orientation and view.

Table 5-1 shows the general statistics of selected observations in Beijing and Singapore. House value is lower, on average, in Beijing (US$ 356,417) than that in Singapore (US$ 465,648). Among structural characteristics variables, mean house lot area in Beijing is larger (197 sq. m.) than in Singapore (123 sq. m.). Average floor level is higher (14 stories) in Beijing than Singapore (8 stories) in the study areas.

As for the sunlight variable, it is interesting to note that the average sunlight hours received by the condominium units in Beijing are much higher than those of Singapore. This could be due to the fact that developers and architects in China do cater to buyers' preference for more sunlight, especially during winter.

We also found that 31% and 37% housing units cannot get sunlight in winter and summer solstices respectively in Beijing (in Singapore, such figures are 28% and 48%). Those results are gotten using master bedroom as the study point. Master bedroom is cold or not mostly affects dwellers utility since if this room does not have sunlight in the daytime, it would be cold when residents sleep.

In Beijing, 51% of housing units in study area have their living rooms facing south (or nearly south), which is much greater than that in Singapore (14%). This phenomena shows the south facing in Beijing is much more important.

Table 5-1 Descriptive statistics

Variable	Beijing			Singapore		
	Min	Mean	Max	Min	Mean	Max
Price (US$)	108484	356417	1316229	240160	465648	969185
Lnprice	11.5944	12.7839	14.0903	12.3891	13.0512	13.7842
Area (sqm)	86	197	430	84	123	409
Storey	1	14	31	1	8	25
New				0	0.79	1
Tenure				0	0.64	1
Parkview	0	0.58	1	0	0.19	1
Poolview				0	0.14	1
SOUTH	0	0.51	1	0	0.14	1
WINTER(Dummy)	0	0.69	1	0	0.72	1
SUMMER(Dummy)	0	0.63	1	0	0.52	1
WINTERAM(Dummy)	0	0.67	1	0	0.51	1
WINTERPM(Dummy)	0	0.67	1	0	0.62	1
WINTER(Min)	0	332	551	0	255	715
SUMMER(Min)	0	213	600	0	155	362
WINTERAM(Min)	0	156	273	0	126	356
WINTERPM(Min)	0	176	278	0	130	359
LEVEL4	0	0.10	1	0	0.11	1
LEVEL8	0	0.10	1	0	0.11	1

5.2. Regression results

We find that there exists strong collinearity between SOUTH and sunlight variables (in winter) in Beijing. Correlation matrices are shown in table 5-2A and table 5-2B.

Table 5-2a Correlation matrix A

Variable	WINTERAM (Dummy)	WINTERPM (Dummy)	WINTER (Dummy)	SOUTH
WINTERAM(Dummy)	1	0.9128	0.9515	0.6579
WINTERPM(Dummy)	0.9128	1	0.9619	0.6396
WINTER(Dummy)	0.9515	0.9619	1	0.6222
SOUTH	0.6579	0.6396	0.6222	1

Table 5-2b Correlation matrix B

Variable	WINTERAM	WINTERPM	WINTER	SOUTH
WINTERAM	1	0.8496	0.9600	0.7704
WINTERPM	0.8496	1	0.9632	0.6759
WINTER	0.9600	0.9632	1	0.7509
SOUTH	0.7704	0.6759	0.7509	1

Using similar models in the previous chapter, we add two more structural variables: $Area^2$, $Storey^2$ since there may exist nonlinear effects of Area and Storey. We also use log-linear model and apply White’s method to adjust for heteroskedasticity.

Table 5-3 Model 1 using dummy variables

Variable	Beijing	Singapore
Area (sqm)	0.0097801*** (0.000239)	0.010842*** (0.000630)
$Area^2$	-9.16E-06*** (5.16E-07)	-1.86E-05*** (2.10E-06)
Storey	0.013782*** (0.001885)	0.009228*** (0.001262)
$Storey^2$	-0.000233*** (6.47E-05)	9.57E-06 (5.27E-05)
New		0.020034*** (0.007322)
Tenure		0.263448*** (0.009710)
Parkview	-0.015817 (0.009740)	-0.013861** (0.005603)
Poolview		0.023317*** (0.005240)
WINTER(Dummy)		-0.034967*** (0.005173)
SUMMER(Dummy)	-0.006923 (0.007845)	0.011396** (0.005024)
SOUTH	0.070181*** (0.010146)	0.015146** (0.007095)
No. of Observations	831	1084
Adj. R-squared	0.9617	0.9691
F-statistic	1159.24	1029.12

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Figures in parenthesis are std. errors.
Coefficients of constant and time dummies are not listed.

Comparative results of hedonic regressions are showed in table 5-2 to table 5-5. Considering collinearity between SOUTH and winter sunlight variables in Beijing, we exclude winter sunlight variables in model 1 and model 3. Models using WINTERAM and WINTERPM (model 2 and model 4) are only applicable to the data in Singapore.

Table 5-4 Model 2 using dummy variables

Variables	Singapore
Area (sqm)	0.010795*** (0.000638)
$Area^2$	-1.85E-05*** (2.13E-06)
Storey	0.009010*** (0.001267)
$Storey^2$	2.38E-05 (5.25E-05)
New	0.020731*** (0.007414)
Tenure	0.266996*** (0.009471)
Parkview	-0.008311 (0.005575)
Poolview	0.023530*** (0.005123)
WINTERAM(Dummy)	-0.026919*** (0.003742)
WINTERPM(Dummy)	-0.008760** (0.003815)
SOUTH	0.013297** (0.005920)
No. of Observations	1084
Adj. R-squared	0.9693
F-statistic	1031.53

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Figures in parenthesis are std. errors.
Coefficients of constant and time dummies are not listed.

Table 5-5 Model 3 using continuous variables

Variables	Beijing	Singapore
Area (sqm)	0.009759*** (0.000236)	0.010886*** (0.000608)
$Area^2$	-9.13E-06*** (5.13E-07)	-1.87E-05*** (2.02E-06)
Storey	0.013763*** (0.001883)	0.009728*** (0.001249)
$Storey^2$	-0.000232*** (6.47E-05)	-1.52E-06 (5.18E-05)
New		0.020269*** (0.007241)
Tenure		0.264609*** (0.009324)
Parkview	-0.015364 (0.009678)	-0.005413 (0.005520)
Poolview		0.022823*** (0.005204)
WINTER		-8.96E-05*** (8.79E-06)
SUMMER	-1.31E-05 (2.32E-05)	2.96E-06 (1.09E-05)
SOUTH	0.069711*** (0.010401)	0.020595*** (0.006180)
No. of Observations	831	1084
Adj. R-squared		0.9705
F-statistic		1081.30

NOTE:

*** indicates significant at 1% critical level.

** indicates significant at 5% critical level.

*indicates significant at 10% critical level.

All standard errors are heteroskedasticity robust.

Figures in parenthesis are std. errors.

Coefficients of constant and time dummies are not listed.

Table 5-6 Model 4 using continuous variables

Variables	Singapore
Area (sqm)	0.010882*** (0.000604)
$Area^2$	-1.87E-05*** (2.01E-06)
Storey	0.009869*** (0.001255)
$Storey^2$	-6.40E-06 (5.20E-05)
New	0.019762*** (0.007236)
Tenure	0.264931*** (0.009234)
Parkview	-0.008912 (0.005821)
Poolview	0.023683*** (0.005025)
WINTERAM	-7.52E-05*** (1.24E-05)
WINTERPM	-0.000101*** (1.17E-05)
SOUTH	0.020806*** (0.005889)
No. of Observations	1084
Adj. R-squared	0.9706
F-statistic	1084.16

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Figures in parenthesis are std. errors.
Coefficients of constant and time dummies are not listed.

Table 5-7 and 5-8 are regression results using data in Beijing. We test the influences of variable WINTER (Dummy), WINTER (Min), WINTERAM (Dummy), WINTERPM (Dummy), WINTERPM (Dummy) and WINTER (Min) separately.

Table 5-7 Regression results from Beijing data

Variables	Model 5	Model 6
Area (sqm)	0.009942***	0.009779***
	(0.000255)	(0.000252)
$Area^2$	-9.46E-06***	-9.21E-06***
	(5.50E-07)	(5.40E-07)
Storey	0.015201***	0.014180***
	(0.001869)	(0.001888)
$Storey^2$	-0.000258***	-0.000226***
	(6.51E-05)	(6.56E-05)
Parkview	-0.050397***	-0.039417***
	(0.007975)	(0.008502)
WINTER(Dummy)	0.016226*	
	(0.008848)	
WINTER		7.38E-05***
		(1.85E-05)
No. of Observations	831	
Adj. R-squared	0.9590	0.9597
F-statistic	1142.17	1163.12

NOTE:

*** indicates significant at 1% critical level.

** indicates significant at 5% critical level.

*indicates significant at 10% critical level.

All standard errors are heteroskedasticity robust.

Figures in parenthesis are std. errors.

Coefficients of constant and time dummies are not listed.

Table 5-8 Regression results from Beijing data

Variables	Model 7	Model 8	Model 9	Model 10
Area (sqm)	0.009947***	0.009987***	0.009746***	0.009881***
	(0.000256)	(0.000258)	(0.000244)	(0.000257)
$Area^2$	-9.47E-06***	-9.52E-06	-9.22E-06***	-9.35E-06***
	(5.50E-07)	(5.56E-07)	(5.28E-07)	(5.52E-07)
Storey	0.015223***	0.015396***	0.013632***	0.015041***
	(0.001873)	(0.001879)	(0.001892)	(0.001889)
$Storey^2$	-0.000259***	-0.000263***	-0.000210***	-0.000250***
	(6.51E-05)	(6.56E-05)	(6.57E-05)	(6.55E-05)
Parkview	-0.050757***	-0.053339***	-0.032513***	-0.048586***
	(0.008286)	(0.008118)	(0.008975)	(0.007910)
WINTERAM(Dummy)	0.015791*			
	(0.009008)			
WINTERPM(Dummy)		0.010123		
		(0.008923)		
WINTERAM			0.000194***	
			(3.74E-05)	
WINTERPM				8.15E-05**
				(3.25E-05)
No. of Observations	831			
Adj. R-squared	0.9590	0.9589	0.9604	0.9552
F-statistic	1141.34	1138.40	1181.02	1145.27

NOTE:
*** indicates significant at 1% critical level.
** indicates significant at 5% critical level.
*indicates significant at 10% critical level.
All standard errors are heteroskedasticity robust.
Figures in parenthesis are std. errors.
Coefficients of constant and time dummies are not listed.

5.3. Structural variables

Coefficients of variables show the expected sign especially our focus: sunlight variables. In both cities, structural variables like floor area and floor level are positive and significant at 1% level. $Area^2$ and $Storey^2$ are negative because with the increase of Area and Storey, house price shows declined growth rate. However, $Area^2$ and $Storey^2$ are only significant in Beijing.

5.4. View variables

All Parkview variables are negative and insignificant in most models. This is probably due to the fact that most units having parkview face the north (in Beijing). Such units are close to roads, therefore noisier and units facing north cannot receive sunlight in winter, which would likely dampen house prices.

In Singapore, Parkview is significant only in one model. As mentioned in chapter 4, reason may lies in that in Hillview district, there are plenty of trees and green belts besides natural parks. All households can enjoy view of vegetation and access to parks quite easily. Parkview in living room is not regarded as valuable attribute. Another explanation is that in Hillview district, view of Bukit Timah Nature Reserve is different from common parkview. Hillview at night sometimes causes black vision and is not thought as pleasant.

In Singapore, view of swimming pool is much preferred. Poolview is positive and significant at 1% level. House with poolview has a premium of 2.36% (in model 1) of the average selling price. Housing units with freehold tenure or 999 years leasehold are also more valuable as expected.

In this study, we use dummy variable to represent the existence of parkview, which is not very accurate. Applying GIS to control the quality of Parkview may be one of future research topics.

5.5. Sunlight variables

Similarly, we analyze the impact of sunlight in terms of two sets of models: models using dummy variables and continuous variables.

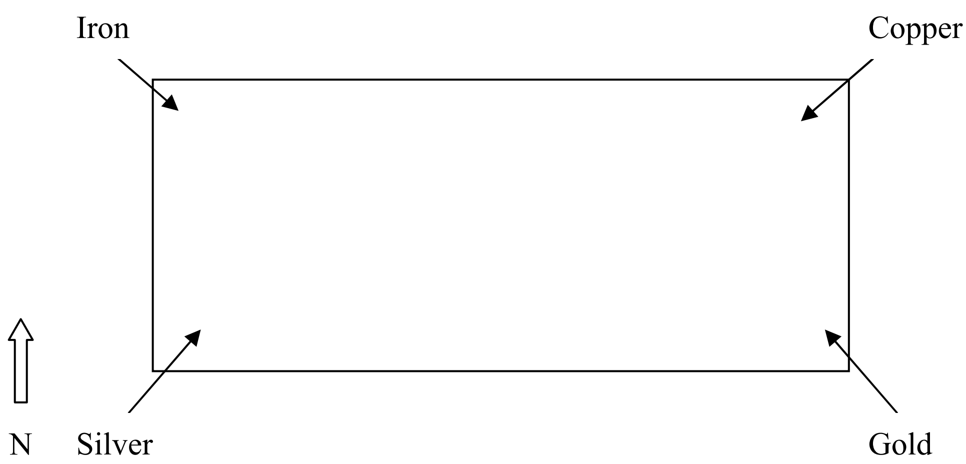
5.5.1. Dummy variables

WINTER (Dummy) has opposite sign in Beijing and Singapore, although both are significant. In Singapore, housing unit having sunlight (represented by master bedroom) during the winter solstice has a drop of 3.44% from the average selling price (in model 1). While in Beijing, according to model 5 in table 5-7, sunlight in winter solstices day adds 1.64% of the average selling price.

WINTERAM (Dummy) and WINTERPM (Dummy) are all significant, also positive in Beijing and negative in Singapore. Orientation is, hence, a very significant factor in both countries but with opposite effect. In Beijing, housing unit having sunlight in the morning of winter solstice has a premium of 1.60% from the average selling price. In Singapore, the reverse is true, with a drop of 2.66% from the average price. WINTERPM (Dummy) is not much significant comparing with WINTERAM (Dummy).

In northern China, buildings are usually described to have four different corners depending on their orientation. The best corner has a south-eastern orientation (hence, known as gold) while the worst corner has a north-western orientation (see figure 5-1).

Figure 5-1 Orientation and the Four Corners



5.5.2. Continuous variables

We further replace sunlight dummies with continuous variables, which represent the specific sunlight duration.

Similarly, we find that in Beijing, sunlight duration in winter has a positive and significant effect on house price but a negative and not very significant impact in summer. For an additional hour of sunlight during the winter solstice, houses in Beijing would cost 0.44% more than the average selling price. For Singapore, again the opposite is true; the longer the sunlight duration, the lower the house price (estimated at 0.54%). SUMMER has no significant effect.

WINTERAM, the sunlight duration on the morning of winter solstice is also positive and significant in Beijing, which is more significant than WINTERPM. The impact in terms of the average selling price works out to be 1.17% for every hour of sunlight.

As for Singapore, both WINTERAM and WINTERPM are significant and negative. The coefficient for WINTERPM reflects a greater diminution in value implying that houses with afternoon sun are less preferred (-0.61% against -0.45). This finding is consistent with our expectation and proves that afternoon sun dampens property price more severely, especially in tropic climate.

Such a phenomenon is due to the difference in the local weather conditions in both countries. In Singapore, lower temperature is preferred while in Beijing, warmer houses are much more valuable. Similar attributes can have different impact on house prices given different local conditions.

In fact, while view is a significant and positive amenity in Singapore with properties designed to achieve maximum view, in particular sea view, households in northern China seem more concerned with orientation and sunlight. In Appendix figure 3, a picture of a proposed development in Tianjin shows that the housing blocks are orientated perpendicular to the river, i.e., sacrificing the river view to achieve better orientation.

5.6. Fengshui variables

In Singapore, SOUTH is found positively significant no matter which model we use. After controlling other variables, south-facing house has a premium of 1.52% on average price (model 1). In Beijing, since there is collinearity among SOUTH and sunlight variables, we can hardly disentangle the effects of Fenghsui and sunlight. The significance of SOUTH can be attributed to three reasons: much sunlight in winter; Fengshui reason; avoiding north wind, which is the main direction of winter wind in Beijing.

Again, we incorporate variables of LEVEL4 and LEVEL8 to test the significance of number of floor level. Regression results dos not show any expected signs of coefficients. To get more reliable results, we may have to know detailed information of households and their preference. For example, most home buyers in project A in

Beijing are expatriates, which may have no traditional Fengshui belief.

5.7. Summary

In this chapter we make a comparison on house price determinants between Beijing and Singapore. Results show that in different climatic condition, orientation has different impact on residential property value. Specifically, much sunlight is highly valued in Beijing while the opposite is true in Singapore. As for sunlight on the morning and afternoon, the latter is not preferred relatively.

Chapter 6 Conclusions and Future Studies

6.1. Introduction

The primary purposes of this study are to analyze the impact of orientation on property prices and make a comparative analysis of house price determinants in Beijing and Singapore, with particular focus on orientation. We use 3D sunlight analysis software to validate the applicability of IT tool on real estate valuation. Results show that orientation does affect the residents' utility and further affect house values.

6.2. Summary of main findings

We calculate the sunlight duration of each housing unit using sunlight analysis software, which is proved to be a useful tool in analyzing property prices. Using the hedonic pricing model, regression results show that structural attributes significantly affect house prices in both cities, which is consistent with previous studies.

Attributes affected by local climatic conditions, however, exhibit different impact. Orientation of housing unit, which affects the amount of sunlight received, has a significant impact on house prices. In Beijing, the impact is generally positive, implying buyers prefer more sun. The opposite is true for tropical Singapore, where buyers shun units with afternoon sun. These effects are translated into general level of prices which buyers are willing to pay. For example, houses with sunlight in winter solstice day in Beijing would have a premium of 1.64% of the average price, while in Singapore, such units would have a drop of 3.44% from the average selling price.

In order to quantify sunlight, we construct variables to represent the actual sunlight duration of housing units. Such models can be used to eliminate subjective judgment in the process of valuation. Specifically, for an additional hour of sunlight during the winter solstice, houses in Beijing would cost 0.44% more than the average price, while in Singapore such houses would cost 0.54% less than the average selling price.

We further analyze the effects of sunlight on the morning and afternoon. Results show that the latter is not preferred, which is consistent with our expectation.

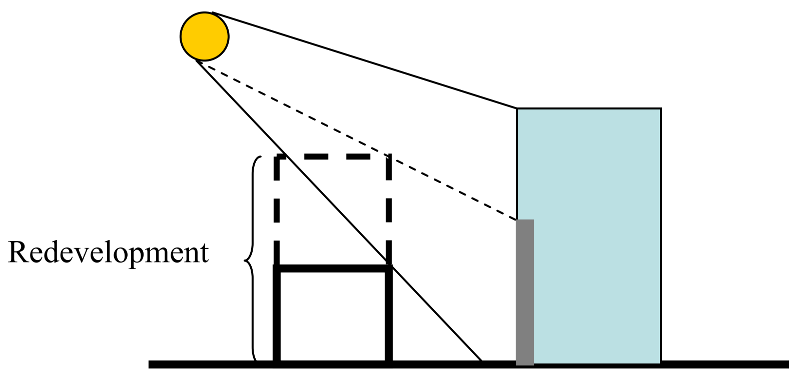
In terms of parkview, it does not show any positive effects in both cities. This is probably due to the fact that most units having parkview face roads, which are nosier than others. In Beijing, properties with parkview face the north and cannot receive sunlight in winter.

The analysis presented here suggests that key determinants of housing prices must be considered separately in each city. Quantifying sunlight will enhance the judgment of subjective variables in the valuation model. Such analysis would be beneficial to real estate developers since they can better predict buyers’ preferences of attributes and incorporate them into their pricing strategy. For the policy-makers, it is important to consider the impact of orientation on property values, especially in cities with high density.

6.3. Future studies

Application of 3D modeling technique developed in this study presents some implications for practical problems and direction of future studies. For example, when a surrounding building is redeveloped (Figure 6-1), does this add a strategic element to the development decision? For the housing unit in the affected building, how much is the value dampened? Future study on this issue will help us better understand the development potential of the site, opportunities for and constraints to site redevelopment.

Figure 6-1 Redevelopment of surrounding building



Beijing looking west

In this study, we use dummy variable to represent the existence of parkview. We do not control the quality of view, which can be measured with the help of GIS. Combing local topographic information with GIS to quantity parkview may be a research topic in the future.

Another kind of future studies is on energy saving. An increase in total floor area, increasing electric appliance ownership, and an increase in demand for heating and cooling characterize the residential sector. Space heating should be the primary concern for energy conservation from a building technology point of view. According to the World Bank, about 3.8 EJ per year is consumed for space heating, accounting for approximately 80–90% of total residential energy use.

Relatively new buildings in cold regions of China still suffer from inadequate insulation, leaky windows, and lack of attention to construction quality. Energy-conservation standards have addressed these issues in part, but further effort is needed to ensure code compliance. Study on sunlight will facilitate the analysis on the heat energy obtained from the sun (winter) or the energy loss caused by too much sunlight (summer). Future cost-benefit analysis may help developers choose economic wall materials and window glasses.

With housing markets becoming more global and investors buying into foreign markets, a deeper understanding of the local impact of price determinants is thus important. Further comparisons between countries and other attributes may offer a better understanding of property values on a broader spatial, urban and social pattern.

Bibliography

Arsenio, E., Bristow, A. L. and Wardman, M. (2006), Stated choice valuations of traffic related noise, *Transportation Research* Part D 11 (2006) 15-31.

Benson,E.D., Hansen,L.J., Schwartz,A.L. and Smersh,G.T.(1998). Pricing Residential Amenities: The Value of a View. *Journal of Real Estate Finance and Economics*, Vol 16, 55-73.

Bourassa, S. C., and Peng, V. S. (1999). Hedonic Prices and House Numbers: The Influence of Feng Shui. *International Real Estate Review*. 1999 Vol. 2 No 1: pp. 79 – 93.

Bourassa, S. C., Hoesli, M. and Sun, J. (2003). What's in a view? *Environment and Planning A,* 36(8): 1427-1450. (2004).

Brown, G. M. & Pollakowski, H. O. (1977). Economics valuation of shoreline, *The Review of Economics and Statistics*, vol. 59, no. 3, pp. 272-278.

Chau, K. W., Ma, V. S. M. & Ho, D. C. W. (2001). The pricing of "luckiness" in the apartment market, *Journal of Real Estate Literature*, vol. 9, no. 1, pp. 31-40.

Chau, K. W., Ng, F. F. & Hung, E. C. T. (2001). Developer's good will as significant influence on apartment unit prices, *Appraisal Journal*, vol. 69, pp. 26-34.

Chay, K. Y. and Greenstone, M. (2004). Does Air Quality Matter? Evidence from the Housing Market. *MIT Department of Economics Working Paper* No. 04-19.

Chiba, T. (1965). Insolation and settlement in the Azusa Ravine, Central Japan, *Tohoku Chiri*, 17(3), p167.

Clauretie, T. M. & Neill, H. R. (2000). Year-round school schedules and residential property values, *Journal of Real Estate Finance and Economics*, vol. 20, no. 3, pp. 311-322.

Cohen, J. P. and Coughlin, C. C. (2005) Airport-Related Noise, Proximity, and Housing Prices in Atlanta FEDERAL RESERVE BANK OF ST. LOUIS *Working Paper*

Correll, M. R., Lillydahl, J. H. & Singell, L. D. (1978). The effects of greenbelts on residential property values: Some findings on the political economy of open space, *Land Economics*, vol. 54, no. 2, pp. 206-217.

Darling,A.(1973). Measuring Benefits Generated by Urban Water Parks. *Land Economics*, Vol 49(1), 22-34.

Davis,G.(1974). An Econometric Analysis of Residential Amenity. *Urban Studies*, Vol11, 217-225.

Debrezion, G., Pels, E. and Rietveld, P. (2006). The Impact of Rail Transport on Real Estate Prices: An Empirical Analysis of the Dutch Housing Markets. *Tinbergen Institute Discussion Paper.* TI 2006-031/3.

Design Code for Residential Buildings GB50096-1999, PRC.

Dewees, D. N. (1976). "The effect of a subway on residential property values in Toronto." *Journal of Urban Economics*, 3: 357-369.

Forrest, D., Glen, J. & Ward, R. (1996). The impact of a light rail system on the structure of house prices, *Journal of Transport Economics and Policy*, vol. 31, no. 4, pp. 15-29.

Freeman, A. M. (1979). Hedonic prices, property values and measuring environmental benefits: A survey of the issues, *Scandinavian Journal of Economics*, vol. 81, pp. 154-171.

Freeman, A. M. (1993). The Measurement of Environmental and Resource Values. Theory and Methods. Washington, D. C.: *Resources for the Future*, 1993, 516 p.

Garnett, A. (1939). Diffuse light and sunlight in relation to relief and settlement in high latitude. *Scot. Geogr. Mag.*, 55 (1939) 271-284

Garrod, G. & Willis, K. (1992). Valuing the goods characteristics – an application of the hedonic price method to environmental attributes, *Journal of Environmental Management*, vol. 34, no. 1, pp. 59-76.

Gatzlaff, D. and M. Smith. 1993. "The Impact of the Miami Metrorail on the Value of Residences Station Locations." *Land Economics*, 69: 54–66.

Gibbons, S. (2003). Paying for Good Neighbours: Estimating the Value of an Implied Educated Community. *Urban Studies*. Vol 40, Numver 4/ April 2003. 809-833.

Gillard, Q. (1981). The effect of environment amenities on house values: The example of a view lot, *Professional Geographer*, vol. 33, pp. 216-220.

Gilles, J and Kulshreshtha, S. (1993). Economic Evaluation of Aesthetic Amenities: A Case Study of River View. *Water Resource Bulletin* 29: 257-66.

Glicksman, L. R., Norford, L. K. and Greden, L. V. (2001). Energy Conservation in Chinese Residential Buildings: Progress and Opportunities in Design and Policy, *Annual Review of Energy and the Environment,* Vol. 26: 83-115 (Volume publication date November 2001).

Grass, R. G. (1992). "The estimation of residential property values around transit station sites in Washington, D.C." *Journal of Economics and Finance*, 16: 139-146.

Heschong, L., Mahone, D., Kuttaiah, K., Stone, N., Chappell, C., McHugh, J., Burton, J., Okura, S., Wright, R., Erwin, B., Holtz, M., Skylighting and retail sales (1999): an investigation into the relationship between daylighting and human performance. Fair Oaks, CA: The Heschong Mahone Group, 1999.

Hoch, I. and Drake, J. (1974). Wages, climate and the quality of life, *Journal of Environmental Economics and Management*, **1**, 268-265 (1974).

Horikoshi, T. and Kagami, K. (1990). Influence of Insolation and Topography on the Landscape of Settlement in the Nyu Ravine, Nara. *Energy and Buildings,* 15-16, (1990/91) 385-389.

Hughes, W. T. Jr. and C.F. Sirmans (1992), .Traffic Externalities and Single-Family House Prices., *Journal of Regional Science* 32(4), 487-500.

Kain, J. F. & Quigley, J. M. (1970). Measuring the value of housing quality, *Journal of the American Statistical Association*, vol. 65, pp. 532-548.

Kennedy P.E. (1981) Estimation with Correctly Interpreted Dummy Variables in Semi-Logarithmic Equations, *American Economic Review*, 71, p. 801.

Kohlhase, J. E. (1991). The impact of toxic waste sites on housing values, *Journal of Urban Economics*, vol. 30, pp. 1-26.

Kroelinger, M. D. (2005). Daylight in buildings. *Implications, www.informedesign.umn.edu.* Vol 03, Issue 3.

Lake,I.R., Lovett,A.A., Bateman,I.J. and Langford,I.H.(1998). Modeling Environmental Influences on Property Prices in an Urban Environment. *Computers, Environment and Urban System*s, Vol 22, 121-136.

Lake,I.R., Lovett,A.A., Bateman,I.J. and Day,B.H.(2000a). Using GIS and Large-scale Digital Data to Implement Hedonic Pricing Studies. *International Journal of Geographical Information Science*, Vol 14, 521-541.

Lake,I.R., Lovett,A.A., Bateman,I.J. and Day,B.H.(2000b). Improving Land Compensation Procedures via GIS and Hedonic Pricing. *Environment and Planning C: Government and Policy*, Vol 18, 681-696.

Lancaster, K. J. (1966). A new approach to consumer theory, *Journal of Political Economy*, vol. 74, pp. 132-157.

Leslie, R. P. (2003). Capturing the daylight dividend in buildings: why and how? *Building and Environment* 38 (2003) 381 – 385.

Li, M. M. & Brown, H. J. (1980). Micro-neighbourhood externalities and hedonic housing prices, *Land Economics*, vol. 56, no. 2, pp. 125-141.

Longley, P., Higgs,G. and Martin,D.(1993). A GIS-Based Appraisal of Council Tax Valuations. *Journal of Property Valuation and Investment*, Vol 11, 275-283.

Maddison, D. and Bigano, A. (2003). The amenityvalue of the Italian climate. *Journal of Environmental Economics and Management.* 45 (2003) 319 – 332.

Ma, S.X., Li, Y., (2003). House price and its determinations in Beijing based on hedonic model. *Journal of Civil Engineering*, 36(9):59-64 (in Chinese).

McCluskey, W. J., Deddis, W. G. and Lamont, I. G. (1999), The Application of Surface Generated Interpolation Models for the Prediction of Residential Property Values, *presented at IAAO Conference on Assessment Administration*, Las Vegas, United States, pp 1-19.

Mcleod,P. B. (1984). The Demand for Local Amenity: A Hedonic Price Analysis. *Environment and Planning*, Vol, 389-400.

Morris, E. W., Woods, M. E. & Jacobson, A. L. (1972). The measurement of housing quality, *Land Economics*, vol. 48 (4), pp. 383-387.

Ne'eman, E. and Shrifteilig, D. (1982). Daylighting of Buildings in a Hot Climate. *Energy and Buildings, 4* (1982) 195-204.

Nelson, R. H. (1972) Housing Facilities, Site Advantages and Rent. *Journal of Regional Science*, 12 (1972), 249-60.

Ooi. T. L. (2005). Initial Property Launches: What Determines the Take-up Rate? *Working Paper of Department of Real Estate,* NUS.

Orford, S. (1988). Valuing location in an urban housing market, *in the Proceedings of the 3rd International Conference on GeoComputation*, United Kingdom, University of Bristol.

Paterson, R. W. and Boyle, K. J.(2002). Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models, *Land Economics*, Vol 78(3), 417-425.

Ridker, R. G. & Henning, J. A. (1967). The determinants of residential property values with special reference to air pollution, *The Review of Economics and Statistics*, vol. 49, pp. 246-257.

Rodriguez, M. & Sirmans, C. F. (1994). Quantifying the value of a view in single-family housing markets, *Appraisal Journal*, vol. 62, pp. 600-603.

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition, *Journal of Political Economy*, vol. 82, no. 1, pp. 35-55.

Seiler,M.J., Bond,M.T. and Seiler,V.L(2001). The Impact of World Class Great Lakes Water Views on Residential Property Values. *Appraisal Journal*, Vol 69(3), 287-295.

Shao, J. (1990). Calculation of Sunshine Duration and Saving of Land Use in Urban Building Design. *Energy and Buildings, 15 - 16* (1990/91) 407-415.

Silverstein, C. (1977). A Dual-Mode Internal Window Management Device for Energy Conservation. *Energy and Buildings,* 1 (1977) 51-56.

Sui, H. G., Chen, S. L. and Zhu, Q. (2004). Design and Implementation of Sunlight Analysis System Based on CyberCity GIS. *Computer Application and Research (in Chinese)*, 2004, Page: 16-19

Tse, R. Y. C. & Love, P. E. D. (2000). Measuring residential property values in Hong Kong, *Property Management*, vol. 18, no. 5, pp. 366-374.

Viitanen, K. Hyyppa, J. and Ronnholm, P. (2005). The Use of Laser Scanning Data in Real Estate Analyses. FIG Commission 9, CIREA and HKIS Symposium – Property Valuers Fronting the Triple Bottom Lines of Economic, Environment and Social Conflicts, Xian, China P. R., 16-20 October 2005.

Wen, H. Z., Jia, S. H. and Guo, X. Y. (2005). Hedonic price analysis of urban housing: An empirical research on Hangzhou, China. *Journal of Zhejiang University SCIENCE*, 2005, 907-914.

Wyatt, P. (1996). The Development of a Property Information System for Valuation Using a Geographical Information System, *Journal of Property Research*, Vol 13, 317-336.

Yang, Z. (2001). An application of the hedonic price model with uncertain attribute - The case of the People's Republic of China. *Property Management*. Mar 2001 Volume: 19 Issue: 1 Page: 50 – 63.

Yu,S.M. and Chai, C.H. (2005). Obstruction of view and its impact on residential apartment prices. *Pacific Rim Property Research Journal*, 11 (3), pp. 299-315.

Appendices

Figure A-1 Study area in Singapore

Figure A-2 Site plan

The Petals

Hillview Regency

Hillington Green

Project A in Beijing

Figure A-3 Model of a proposed development in Tianjin

Table A-1 White Heteroskedasticity Test

White Heteroskedasticity Test:

F-statistic	32.06976	Probability	0.000000
Obs*R-squared	970.8572	Probability	0.000000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1 1084
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002084	0.023229	0.089716	0.9285
AREA	-0.000555	0.000322	-1.721291	0.0856
AREA^2	6.17E-06	7.61E-07	8.104988	0.0000
AREA*STOREY	-5.68E-06	5.84E-06	-0.972940	0.3309
AREA*NEW	-4.95E-05	7.77E-05	-0.637917	0.5237
AREA*TENURE	-0.000653	0.000131	-4.964950	0.0000
AREA*PARKVIEW	5.21E-05	0.000129	0.405129	0.6855
AREA*POOLVIEW	-5.90E-05	7.64E-05	-0.771905	0.4404
AREA*WINTERD	-6.92E-05	7.26E-05	-0.952561	0.3411
AREA*SUMMERD	0.000185	7.77E-05	2.383301	0.0174
AREA*PETALS	0.000257	8.30E-05	3.097387	0.0020
AREA*Q2	-0.000378	0.000223	-1.693349	0.0908
AREA*Q3	-0.000783	0.000282	-2.778979	0.0056
AREA*Q4	-0.000452	0.000337	-1.341301	0.1802
AREA*Q5	-0.000295	0.000249	-1.184312	0.2366
AREA*Q6	-0.000458	0.000191	-2.394228	0.0169
AREA*Q7	-0.000601	0.000190	-3.163407	0.0016
AREA*Q8	-0.000649	0.000209	-3.110638	0.0019
AREA*Q9	-0.000609	0.000186	-3.267743	0.0011
AREA*Q10	-0.000724	0.000206	-3.521960	0.0005
AREA*Q11	-0.000725	0.000192	-3.772552	0.0002
AREA*Q12	-0.000679	0.000174	-3.905793	0.0001
AREA*Q13	-0.000694	0.000184	-3.769291	0.0002
AREA*Q14	-0.000685	0.000181	-3.788866	0.0002
AREA*Q15	-0.000551	0.000191	-2.878634	0.0041
AREA*Q16	-0.000695	0.000214	-3.243009	0.0012
AREA*Q17	-0.000698	0.000210	-3.325636	0.0009
AREA*Q18	-0.000802	0.000231	-3.473856	0.0005
AREA*Q19	-0.000472	0.000200	-2.362884	0.0184

AREA*Q20	-0.000714	0.000224	-3.181356	0.0015
AREA*Q21	-0.000863	0.000167	-5.168428	0.0000
AREA*Q22	-0.000596	0.000190	-3.131296	0.0018
STOREY	0.002724	0.001275	2.136916	0.0329
STOREY^2	1.09E-05	1.06E-05	1.024053	0.3061
STOREY*NEW	-0.003054	0.000846	-3.609385	0.0003
STOREY*TENURE	-0.001652	0.000637	-2.593796	0.0097
STOREY*PARKVIEW	-0.000120	0.000335	-0.358029	0.7204
STOREY*POOLVIEW	2.96E-05	0.000362	0.081661	0.9349
STOREY*WINTERD	-0.000430	0.000195	-2.205382	0.0277
STOREY*SUMMERD	1.81E-05	0.000185	0.097462	0.9224
STOREY*PETALS	-0.001374	0.000682	-2.016516	0.0441
STOREY*Q2	0.000516	0.000604	0.854049	0.3933
STOREY*Q3	0.000854	0.000658	1.297789	0.1947
STOREY*Q4	0.000785	0.000713	1.100201	0.2716
STOREY*Q5	0.000729	0.000617	1.181842	0.2376
STOREY*Q6	0.001129	0.000596	1.895594	0.0584
STOREY*Q7	0.000738	0.000599	1.231469	0.2185
STOREY*Q8	0.001036	0.000612	1.692017	0.0910
STOREY*Q9	0.000712	0.000611	1.164581	0.2445
STOREY*Q10	0.000845	0.000615	1.373582	0.1699
STOREY*Q11	0.000968	0.000683	1.418203	0.1565
STOREY*Q12	0.000629	0.000614	1.024284	0.3060
STOREY*Q13	0.002381	0.000860	2.767232	0.0058
STOREY*Q14	0.002207	0.000889	2.481580	0.0133
STOREY*Q15	0.002168	0.000856	2.533887	0.0115
STOREY*Q16	0.001821	0.000659	2.764122	0.0058
STOREY*Q17	0.000792	0.000598	1.325040	0.1855
STOREY*Q18	0.000919	0.000623	1.475555	0.1404
STOREY*Q19	0.000712	0.000633	1.126047	0.2605
STOREY*Q20	-0.000557	0.001307	-0.426172	0.6701
STOREY*Q21	0.002590	0.000972	2.665264	0.0078
STOREY*Q22	0.003796	0.001175	3.231265	0.0013
NEW	0.020058	0.012104	1.657148	0.0979
NEW*TENURE	-0.022778	0.020537	-1.109130	0.2677
NEW*PARKVIEW	-0.005857	0.005697	-1.028064	0.3042
NEW*POOLVIEW	0.001099	0.004427	0.248277	0.8040
NEW*WINTERD	0.003324	0.003851	0.863068	0.3883
NEW*SUMMERD	-0.007314	0.004420	-1.654932	0.0983
NEW*PETALS	0.006619	0.007588	0.872242	0.3833
NEW*Q2	0.016284	0.021959	0.741564	0.4586
NEW*Q3	0.011501	0.011060	1.039893	0.2987
NEW*Q4	0.029848	0.033103	0.901646	0.3675
NEW*Q5	0.008903	0.023431	0.379965	0.7041

NEW*Q6	0.000360	0.010935	0.032881	0.9738
NEW*Q7	0.037576	0.019434	1.933464	0.0535
NEW*Q8	0.038121	0.020428	1.866111	0.0624
NEW*Q9	0.040626	0.019175	2.118698	0.0344
NEW*Q10	0.046320	0.020898	2.216482	0.0269
NEW*Q11	0.046898	0.020551	2.282086	0.0227
NEW*Q12	0.046544	0.018147	2.564846	0.0105
NEW*Q13	0.037750	0.020473	1.843903	0.0655
NEW*Q14	0.039542	0.020366	1.941571	0.0525
NEW*Q15	0.019444	0.020170	0.963986	0.3353
NEW*Q16	0.039388	0.020853	1.888812	0.0593
NEW*Q17	0.048775	0.021199	2.300822	0.0216
NEW*Q18	0.055910	0.022626	2.471054	0.0137
NEW*Q19	0.026666	0.019476	1.369186	0.1713
NEW*Q20	0.053337	0.021091	2.528879	0.0116
NEW*Q21	0.163567	0.048642	3.362690	0.0008
NEW*Q22	0.117052	0.052088	2.247187	0.0249
TENURE	0.016104	0.031667	0.508531	0.6112
TENURE*PARKVIEW	-0.023202	0.009571	-2.424151	0.0156
TENURE*POOLVIEW	-0.000207	0.004339	-0.047675	0.9620
TENURE*WINTERD	-0.002033	0.005548	-0.366413	0.7141
TENURE*SUMMERD	-0.011443	0.005285	-2.165287	0.0306
TENURE*PETALS	0.018241	0.023184	0.786809	0.4316
TENURE*Q2	0.076613	0.040572	1.888313	0.0593
TENURE*Q3	0.092129	0.026536	3.471792	0.0005
TENURE*Q4	0.096675	0.052072	1.856545	0.0637
TENURE*Q5	0.068058	0.040339	1.687135	0.0919
TENURE*Q6	0.067850	0.023712	2.861423	0.0043
TENURE*Q7	0.112133	0.035142	3.190846	0.0015
TENURE*Q8	0.117242	0.035935	3.262642	0.0011
TENURE*Q9	0.115119	0.034648	3.322495	0.0009
TENURE*Q10	0.127626	0.037306	3.421054	0.0007
TENURE*Q11	0.125996	0.035476	3.551642	0.0004
TENURE*Q12	0.123974	0.033593	3.690515	0.0002
TENURE*Q13	0.106302	0.034183	3.109786	0.0019
TENURE*Q14	0.100716	0.034393	2.928403	0.0035
TENURE*Q15	0.101085	0.034296	2.947480	0.0033
TENURE*Q16	0.109476	0.034696	3.155301	0.0017
TENURE*Q17	0.102058	0.034222	2.982263	0.0029
TENURE*Q18	0.106639	0.034386	3.101213	0.0020
TENURE*Q19	0.101444	0.035146	2.886347	0.0040
TENURE*Q20	0.098879	0.035923	2.752524	0.0060
PARKVIEW	-0.104490	0.035759	-2.922054	0.0036
PARKVIEW*POOLVIEW	0.013879	0.005828	2.381374	0.0175

PARKVIEW*WINTERD	0.002450	0.006242	0.392555	0.6947
PARKVIEW*SUMMERD	-0.000742	0.004085	-0.181647	0.8559
PARKVIEW*PETALS	0.016370	0.004576	3.577135	0.0004
PARKVIEW*Q2	0.116877	0.039734	2.941457	0.0034
PARKVIEW*Q4	0.078535	0.037113	2.116093	0.0346
PARKVIEW*Q8	0.097086	0.033076	2.935193	0.0034
PARKVIEW*Q9	0.114297	0.033696	3.392010	0.0007
PARKVIEW*Q10	0.122972	0.033856	3.632227	0.0003
PARKVIEW*Q11	0.099185	0.033077	2.998599	0.0028
PARKVIEW*Q12	0.113805	0.033277	3.419955	0.0007
PARKVIEW*Q13	0.126334	0.033901	3.726559	0.0002
PARKVIEW*Q14	0.125162	0.034493	3.628648	0.0003
PARKVIEW*Q15	0.115635	0.034023	3.398719	0.0007
PARKVIEW*Q16	0.117426	0.034613	3.392496	0.0007
PARKVIEW*Q17	0.101814	0.033446	3.044142	0.0024
PARKVIEW*Q18	0.103488	0.033135	3.123201	0.0018
PARKVIEW*Q19	0.106090	0.033049	3.210089	0.0014
PARKVIEW*Q20	0.124335	0.036211	3.433645	0.0006
PARKVIEW*Q21	0.105770	0.034207	3.092076	0.0021
PARKVIEW*Q22	0.105219	0.034262	3.070973	0.0022
POOLVIEW	0.013198	0.012675	1.041278	0.2980
POOLVIEW*WINTERD	0.003248	0.006317	0.514180	0.6073
POOLVIEW*SUMMERD	-0.001894	0.003056	-0.619778	0.5356
POOLVIEW*PETALS	-0.000733	0.007353	-0.099635	0.9207
POOLVIEW*Q2	-0.005250	0.009606	-0.546576	0.5848
POOLVIEW*Q3	-0.006707	0.011681	-0.574141	0.5660
POOLVIEW*Q4	-0.000968	0.012660	-0.076457	0.9391
POOLVIEW*Q5	-0.006301	0.009859	-0.639144	0.5229
POOLVIEW*Q6	-0.008292	0.011142	-0.744212	0.4570
POOLVIEW*Q7	-0.008853	0.010715	-0.826180	0.4089
POOLVIEW*Q8	-0.011920	0.011621	-1.025772	0.3053
POOLVIEW*Q9	-0.009209	0.010550	-0.872940	0.3829
POOLVIEW*Q10	-0.008456	0.010492	-0.805916	0.4205
POOLVIEW*Q11	-0.007732	0.010705	-0.722231	0.4704
POOLVIEW*Q12	-0.007241	0.010979	-0.659551	0.5097
POOLVIEW*Q13	-0.004280	0.011131	-0.384481	0.7007
POOLVIEW*Q14	-0.003997	0.011150	-0.358524	0.7200
POOLVIEW*Q15	-0.012156	0.013066	-0.930396	0.3524
POOLVIEW*Q16	-0.002588	0.011990	-0.215864	0.8291
POOLVIEW*Q17	-0.014863	0.017799	-0.835035	0.4039
POOLVIEW*Q18	-0.008090	0.011355	-0.712500	0.4764
POOLVIEW*Q19	-0.005853	0.018056	-0.324160	0.7459
POOLVIEW*Q20	0.019396	0.016615	1.167374	0.2434
POOLVIEW*Q21	0.001682	0.011400	0.147556	0.8827

POOLVIEW*Q22	-0.006847	0.012704	-0.538933	0.5901
WINTERD	-0.007165	0.009198	-0.778937	0.4362
WINTERD*SUMMERD	0.007242	0.003444	2.103111	0.0357
WINTERD*PETALS	0.001502	0.003736	0.402028	0.6878
WINTERD*Q2	0.022498	0.009135	2.462890	0.0140
WINTERD*Q3	0.012594	0.010891	1.156299	0.2479
WINTERD*Q4	0.010938	0.019733	0.554321	0.5795
WINTERD*Q5	0.013905	0.008785	1.582873	0.1138
WINTERD*Q6	0.015815	0.008909	1.775212	0.0762
WINTERD*Q7	0.016713	0.008607	1.941773	0.0525
WINTERD*Q8	0.015011	0.008459	1.774588	0.0763
WINTERD*Q9	0.016467	0.008735	1.885147	0.0598
WINTERD*Q10	0.015648	0.008947	1.748927	0.0807
WINTERD*Q11	0.020110	0.008965	2.243270	0.0251
WINTERD*Q12	0.017098	0.008632	1.980781	0.0479
WINTERD*Q13	0.005667	0.010033	0.564844	0.5723
WINTERD*Q14	0.006808	0.010329	0.659081	0.5100
WINTERD*Q15	0.014578	0.009885	1.474729	0.1407
WINTERD*Q16	0.004864	0.009638	0.504596	0.6140
WINTERD*Q17	0.012378	0.009694	1.276838	0.2020
WINTERD*Q18	0.016800	0.008624	1.948015	0.0517
WINTERD*Q19	0.011770	0.008983	1.310233	0.1905
WINTERD*Q20	-0.012991	0.019372	-0.670634	0.5026
WINTERD*Q21	0.004527	0.010929	0.414227	0.6788
WINTERD*Q22	0.014265	0.011010	1.295662	0.1954
SUMMERD	-0.002328	0.012928	-0.180035	0.8572
SUMMERD*PETALS	0.004586	0.004907	0.934537	0.3503
SUMMERD*Q2	-0.018651	0.010205	-1.827533	0.0680
SUMMERD*Q3	-0.019071	0.010125	-1.883635	0.0600
SUMMERD*Q4	-0.019832	0.022463	-0.882857	0.3776
SUMMERD*Q5	-0.013943	0.010141	-1.374876	0.1695
SUMMERD*Q6	-0.017458	0.010246	-1.703934	0.0888
SUMMERD*Q7	-0.017083	0.010064	-1.697456	0.0900
SUMMERD*Q8	-0.010936	0.009848	-1.110472	0.2671
SUMMERD*Q9	-0.019193	0.010249	-1.872708	0.0615
SUMMERD*Q10	-0.014371	0.010507	-1.367828	0.1717
SUMMERD*Q11	-0.018671	0.010553	-1.769372	0.0772
SUMMERD*Q12	-0.016080	0.010128	-1.587728	0.1127
SUMMERD*Q13	-0.008134	0.010335	-0.787016	0.4315
SUMMERD*Q14	-0.005340	0.010806	-0.494139	0.6213
SUMMERD*Q15	-0.007659	0.010640	-0.719840	0.4718
SUMMERD*Q16	-0.011466	0.010474	-1.094746	0.2739
SUMMERD*Q17	-0.010137	0.010401	-0.974582	0.3300
SUMMERD*Q18	-0.016076	0.009939	-1.617392	0.1062

SUMMERD*Q19	-0.013198	0.010625	-1.242248	0.2145
SUMMERD*Q20	0.019469	0.020679	0.941490	0.3467
SUMMERD*Q21	-0.009419	0.011012	-0.855318	0.3926
SUMMERD*Q22	-0.011502	0.011767	-0.977516	0.3286
PETALS*Q2	-0.047233	0.018343	-2.574981	0.0102
PETALS*Q3	-0.050669	0.017751	-2.854463	0.0044
PETALS*Q4	-0.040956	0.017862	-2.292849	0.0221
PETALS*Q5	-0.050199	0.017341	-2.894873	0.0039
PETALS*Q6	-0.044733	0.017394	-2.571825	0.0103
PETALS*Q7	-0.052338	0.016671	-3.139540	0.0018
PETALS*Q8	-0.051386	0.016813	-3.056387	0.0023
PETALS*Q9	-0.051675	0.017244	-2.996690	0.0028
PETALS*Q10	-0.070249	0.019393	-3.622409	0.0003
PETALS*Q12	-0.054629	0.016954	-3.222259	0.0013
PETALS*Q13	-0.038085	0.017329	-2.197769	0.0282
PETALS*Q14	-0.038673	0.020936	-1.847182	0.0651
PETALS*Q15	-0.060009	0.017443	-3.440227	0.0006
PETALS*Q16	-0.062340	0.018510	-3.367860	0.0008
PETALS*Q17	-0.060473	0.018265	-3.310820	0.0010
PETALS*Q19	-0.061342	0.017902	-3.426477	0.0006
PETALS*Q20	-0.035304	0.021834	-1.616935	0.1063
PETALS*Q21	-0.045324	0.017975	-2.521559	0.0119
PETALS*Q22	-0.052879	0.017738	-2.981164	0.0030
Q3	0.049664	0.027374	1.814263	0.0700
Q6	0.018819	0.016156	1.164839	0.2444
Q13	-0.000288	0.011541	-0.024965	0.9801

R-squared	0.896452	Mean dependent var	0.004287
Adjusted R-squared	0.868499	S.D. dependent var	0.023101
S.E. of regression	0.008377	Akaike info criterion	-6.539962
Sum squared resid	0.059789	Schwarz criterion	-5.476148
Log likelihood	3772.389	F-statistic	32.06976
Durbin-Watson stat	2.209792	Prob(F-statistic)	0.000000